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RECLAMATION

Planning - Practice - Results

PROCEEDINGS OF
THE EIGHTH ANNUAL MEETING

WATERLOO, ONTARIO
August 21 - August 24, 1983

CLRA CANADIAN LAND RECLAMATION ASSOCIATION

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PROCEEDINGS OF THE EIGHTH ANNUAL MEETING OF THE CANADIAN LAND RECLAMATION ASSOCIATION

UNIVERSITY OF WATERLOO
WATERLOO, ONTARIO, CANADA
AUGUST 21 TO AUGUST 24, 1983

RECLAMATION

PLANNING
PRACTICE
RESULTS

HOSTED BY

ONTARIO CHAPTER CLRA
FACULTY OF ENVIRONMENTAL STUDIES
UNIVERSITY OF WATERLOO

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FOREWARD

One of the important aspects in the field of land reclamation is experience and the exchange of ideas; the best way of learning is from your successes and failures and from those of your colleagues. The program for the eighth annual meeting of the CLRA was structured to maximize such an exchange. This year's conference was held in southern Ontario, an area rich in reclamation sites such as worked out pits and quarries, mine tailings, pipeline, highway, and electrical transmission line rights-of-way and shoreline restoration.

The theme of this conference was "Planning, Practice, and Results"; all aspects necessary for successful reclamation projects. The technical sessions were divided into six topics:

Planning
Mining Reclamation
Plants in Reclamation
Reclamation - General
Reclamation/Erosion Control
Pits and Quarries, Legislation and Reclamation

A field trip was conducted following the two days of technical sessions. The tour considered the area in Ontario known as the "Golden Horseshoe" and covered reclamation in: an active stone quarry, a river valley crossing by TransCanada Pipelines, and the land reclamation being carried out in Toronto Harbour and along the Lake Ontario shoreline by the Toronto Harbour Commission and the Metropolitan Toronto and Region Conservation Authority.

The papers have been reproduced here much as they were received; my thanks to all authors for the considerable effort which was put into the papers and in adhering to my suggested guidelines for the preparation of these papers.

W.E. Welch
Editor
December 1983

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ADDRESS TO THE EIGHTH ANNUAL MEETING OF THE CANADIAN LAND RECLAMATION ASSOCIATION

UNIVERSITY OF WATERLOO
AUGUST 23, 1983

DR. W.B. MOUNTAIN
Assistant Deputy Minister
Environmental Conservation Service
Environment Canada

INTRODUCTION

I am very pleased to be able to speak to you this evening during your eighth Annual Meeting. I had been asked by Mr. Roberts to express his personal regrets at not being able to be here personally. In politics, nothing is stable and we now have a new minister, Mr. Charles Caccia in place for the past ten days. He has a keen interest in the natural resource area (having been a professional forester) an I know that, with time, he will be taking a keen interest in what your association does.

. . . .

A major concern of the Federal Government in recent years has been the alarming rate at which our national land resource is being degraded. Recent federal and provincial evaluations indicate that the nature and extent of land degradation in Canada is much greater than previously indicated. For years, people have been analyzing and discussing the tensions that exist between development of nonrenewable resources on one hand, and conservation and protection on the other. Indeed, for the past 20 years, public attention and opposition to land disturbances and other degradation processes has focused on the nonmineral, mineral, and energy sectors of our economy. But considering the amount of land devoted to other land uses requiring permanent disturbances and use of land for transportation, pipelines, transmission, urban development, which is some 8.25 million ha, the less than 300,000 ha affected by mining is extremely small.

But it is in the renewable-resource sectors where Canadians have also been "Mining the Land" in a much broader sense for decades. Traditional land use management practices in farming have led to increased erosion, sedimentation, losses of soil structure and fertility, salinization and contamination by chemical residues. For example, most man-induced salinity in Western Canada occurs to varying degrees in very small areas (1-10 ha) but cumulatively they amount to an estimated 2.2 million ha in dry land areas, and a further 100,000 ha in irrigated lands. In Ontario and Quebec, much of the soil loss due to water erosion has been due to the shift to single cropping systems (mainly corn) removal of fence rows, wood lots and densely vegetated areas around streams. In Ontario, over 1 million ha were converted to corn and soy bean production between 1966-1979. The effects of these high erosion rates in Ontario have increased sedimentation and damage of aquatic

environments through the transfer of herbicides, pesticides and fertilizers (mainly phosphorus) to water bodies in the Great Lakes Basin.

Similar erosion and sedimentation problems have resulted from forest management practices, but more important, has been the lack of forest renewal, which has left a huge backlog of nonrestocked forest lands. Five years ago, nonrestocked forest areas were increasing at a rate of 193,000 ha per year. A rate which would have seen the overall backlog double by the end of this decade. In addition, forestry losses and logging practices also affect valuable wildlife habitats and aesthetic landscape values essential to recreation and tourism sectors of the economy.

The overall seriousness of land degradation in Canada is not necessarily the area affected by one individual process or management practice in a given region, but the cumulative total of the whole range of processes causing adverse chemical and physical alterations.

Not all the effects of degradation processes are clear-cut, nor are the long-term effects of degradation clearly understood. Research and monitoring has only seriously focused on these within the past decade. We still do not know enough about the actual changes to land value or long-term soil quality. But enough is known to confirm that the soil degradation processes are growing in extent and degree of severity and must be taken seriously.

Land degradation is a world-wide problem that should concern all Canadians. Rising world population levels and expectations of people continue to exert intolerable pressures on ecological systems everywhere. These pressures seriously threaten the ecological, economic and political stability of the world. For example, the search for farmland, fuel and timber products for the mushrooming population of third world nations has led to the headlong destruction of the world's tropical forests at a rate of 20 million ha per year. A more speculative, but equally serious consequence of the tropical forest loss, is its possible impact on world climate. Such losses add to the rapidly increasing carbon dioxide concentrations in the atmosphere, with the resultant greenhouse effect warming the earth, especially at the poles with serious consequences for agriculture and coastal communities.

Over 2 billion ha of the world's dryland areas (an area twice the land mass of Canada) are susceptible to a high rate of

desertification, brought in by overgrazing, overcropping, and general mismanagement.

Canadians cannot expect to escape the repercussions of these world-wide developments and cannot be complacent. Canada will continue to be expected to supply food, energy, forest product and minerals to meet an escalating global demand, assuming there is purchasing power abroad and Canadian exports remain internationally competitive. This will put even greater stress on our deteriorating land resources, with, as I noted earlier, further aggravation of increasing climatic variability and indications of long-term climatic change on a global scale. The arid areas of central North America are particularly susceptible to weather change.

Canada needs to respond to the predictions that serious resource shortages and environmental degradation will increase on a world scale. Our ability to respond to this will depend on how well we control the deterioration of our own renewable resource base. To do this, it is essential that the decisions relating to resource development be based on the knowledge of longer term environmental and resource implications. The role of government in these decisions is to look outward and determine what role the country's natural resources will play in the international market place.

The concept of "Sustainable Development" has become a key to the development of our natural resources. The concept was first articulated for Canada in the November 1981 federal budget, in which it was affirmed that conservation will be integrated into Canada's future resource development.

> "The maintenance of the quality of our water, our air, and our soil is essential to our long-term development and to the quality of life to which that development must contribute."

Canada will continue to rely on its traditional resource based economy to provide the economic foundations for its future development. Thus the preservation and enhancement of soil structure and fertility, the sustainability of forest yields, multiple resource use, and the maintenance of agricultural land and wetlands will be major renewable resource issues, while the focus for nonrenewable resources including energy will be on economically efficient and environmentally appropriate development. A deteriorating resource base will make it more costly or perhaps impossible to compete in the international marketplace. The longer Canada waits to reduce the impacts of

degradation from resource development, the more difficult it will be to undertake remedial measures and still main competitive (in the international marketplace).

Much of the concern with global scale of degradation processes was reflected in the 1980 publication of the "World Conservation Strategy." The Strategy has three major objectives. The are:

1. To maintain essential ecological process and life support systems on which human survival depends. . . These include soil regeneration, the recycling of nutrients and the cleansing of air and water;

2. To preserve genetic diversity . . . which affects agriculture, forestry, fisheries, and other industries which depend upon living resources; and

3. To make sustainable use of species and ecosystems such as fish and other wildlife, forests, and agricultural lands.

In 1982, the Federal Government adopted the World Conservation Strategy as a model for developing federal government conservation strategies, and as a first step towards ensuring environmental quality and continuing growth and prosperity of our resources based economy. Our Department has been given the responsibility of developing strategies for conserving renewable resources and maintaining environmental quality in areas under federal jurisdiction and to work with the provinces in developing complementary strategies for areas of shared responsibilities and of mutual concern.

In 1981, a Federal Policy on Land Use was adopted by Cabinet to define principles relating to land use and guidelines for the effects of the federal government's activities on the use of private and public lands throughout the nation. Meetings have been held with key federal ministers and all the provinces, to ensure compatibility of this policy with provincial responsibilities. The relevant federal agencies have been instructed by cabinet to provide for this policy in federal/provincial agreements relating to renewable resources and in the environmental assessment review process. The Interdepartmental Committee on Land has been the establishment (chaired by Environment Canada) to develop practical solutions and guidelines, and to bring serious land issues resulting from federal activities to the attention of the government. This Committee has been charged with the implementation of strategies related to soil degradation as Canada's response to the World Conservation Strategy.

My Department has identified seven conservation and environmental issues which will require intensified efforts including the use of additional resources. These are: toxic substances; acid rain; water supply and quality; forest renewal; climatic change; protection of national heritage lands, and northern development.

In addition, to increased funding for research, testing and monitoring, a major thrust of our Department has been to support joint agreements with the provinces. In the past year, for example, agreements for the regulation of the Ottawa River, Great Lakes water quality and mercury studies have been completed as well as a Canadian Caribou Conservation Agreement with Manitoba and Saskatchewan. There is also an agreement with the prairie provinces to prevent crop damage from wildlife.

Concerns over the deteriorating forest and agriculture sectors have resulted in the adoption of a Forest Renewal Strategy by our Department and an Agri-Food Strategy by Agriculture Canada, both of which have resulted in several hundred million dollars being channelled into these two industries through federal/provincial agreements. Forest renewal agreements have been signed with five provinces already and three more will be completed this year. Most of the agreements are mission-oriented, dealing with the effects of forest diseases and pesticides, soil chemistry, acid rain, implementation of improved forest management practices, and, above all, reforestation and protection. In response to serious soil and water conservation problems in the Prairie Provinces, the federal government is relocating the national Hydrology Research Institute in Saskatoon and a new Soil and Water Research Institute is under consideration by Agriculture Canada for the same city.

Under the direction of the Canada Centre for Mineral and Energy Technology, the problems of dispersing and reclaiming uranium mine tailings led to the development of a cooperative Uranium Mine Tailings Program in conjunction with industry, and the Atomic Energy Control Board and the Environmental Protection Service of our Department. Currently, a parallel program is in the development stages for acid sulphide ore tailings.

It is evident from public concerns over the extent of environmental degradation that planning for the conservation of renewable resources and for appropriate reclamation practices in the nonrenewable resource sector is essential to sustain Canada's economic development.

The successful integration of conservation and reclamation measures into the planning process for resource development will demand even greater knowledge from a wide range of specialists. It will undoubtedly increase the pressure on such specialists in the government, universities and private sector to find practical cost-effective solutions to conservation and reclamation problems arising from resource development. Enough is known, however, to apply current knowledge to considerable benefit both as preventative and remedial measures in the advanced planning stages of current and future activities. We do know enough today to be able to reduce the degradation processes that occur in the agricultural, forestry, and water resource sectors. We also have sufficient knowledge to rehabilitate disturbances associated with sand and gravel pits, pipelines, transportation and power transmission corridors.

But under our harsh and somewhat unique environmental conditions, reclamation is still a relatively new technology, particularly as applied to certain mineral and energy developments, long-term, successful packaged solutions are still scarce. In the long-term, we have to develop a positive approach towards achieving economically and environmentally acceptable reclamation techniques.

In today's period of economic restraint, the key questions is not one of overall ability to pay, but rather one of priorities and the willingness to redirect economic resources from other uses to reclamation. The extent to which we will go to protect the environment is essentially a function of economic priorities and the pressures exerted by society.

Therefore, it is critical that senior levels of government and the developers of Canada's resources develop techniques for the best possible evaluation of whether or not an area can be reclaimed. Governments must determine whether or not the potential benefits of conservation and reclamation measures are worth the economic cost, particularly in remote areas where there are major difficulties because of limiting physical, chemical, locational and climatic conditions.

These will be difficult choices between competing land uses. In some cases, the development of particular nonrenewable resources are essential to economic prosperity despite the nonreversible environmental degradation which will result.

Finally, I would like to leave you with two considerations that are essential to the successful planning of conservation and reclamation practices. We must consider additional landuse

opportunities and include the public in all advanced planning which results in a drastic temporary or permanent alteration of a particular land area.

For example, if the development of a new mine requires the construction of a major new road or railway into a previously inaccessible but aesthetically attractive area, consideration should be given (in the advanced planning stages) to potential alternative or parallel land use opportunities such as forestry or recreation and tourism as well as the fragility of the ecosystems being invaded.

In other cases, such as the extraction of sand, gravel or coal, it is essential that clearly defined land use options for the subsequent use of the land are established in consultation with the public. Early public involvement and acceptance can considerably reduce potential conflict, reclamation problems and ultimately costs.

The challenge facing you as practising reclamationists, resource planners, managers and concerned Canadians is one of emphasizing the importance of implementing cost-effective conservation and reclamation measures in the advanced planning stages of all resource development activities that have the potential to degrade or permanently alter the land and its potential for other uses.

SESSION I

KEYNOTE ADDRESSES

Dr. J.V. Thirgood - Chairman

PIONEERING A PERMANENT LAND: THE MEANING OF RECLAMATION

Edward G. Pleva
London, Ontario

Today we are faced with a significant credibility gap. A few years ago President Jimmy Carter called on leading scientists and economists to forecast the state of the world in 2000 A.D. The results were published as The Global 2000 Report to the President. Another president, Ronald Reagan, recently asked other leading scientists and economists to look at 2000 A.D. They did and, using the same body of knowledge as the earlier group, came up with findings much different from the earlier report. No wonder the citizen-taxpayer is confused. What is right? What is wrong? Perhaps it's like the successful graduate who visited his Economics Professor twenty years after graduation. The Professor said, "I must hand this examination to my assistant who will proctor for me this hour. I will be right back. Perhaps you would like to see a copy of the examination while I am away". When the Professor returned the visitor said, "This is the same examination you gave us twenty years ago". The Professor replied, "Not really. You see, the questions are the same: the answers are different".

The language we use, precisely the words themselves, help us to understand better what we are talking about. I will use three words often and, therefore, we should go to the dictionary to see what the words are trying to tell us. First, land means the natural resources as a factor of production. It is the full storehouse of all the natural things man uses: air, water, soil, vegetation, animals, minerals. The second word, resources, is a sermon in conservation because it means "to surge up again". We have every right to use resources but they should be used in such a way that they surge up again in perpetual productivity not only for ourselves but for the others who follow us. The third word, reclamation, is most unusual in its challenge. Reclamation means to cry out or to call for attention. Thus the three words emphasize the meaning of your conference: the wise use of resources in perpetuity.

Do we have a land use philosophy, an ethic, a policy? Some pragmatic people say our policy is what we do. This, as an answer, does not satisfy us and it certainly will not satisfy our children. Aldo Leopold reminded us often that the land ethic is a product of social evolution because nothing so important as an ethic is ever written. The ethic is the reflection of our approach to land and the values we place on our relationship to it. I recall how once in the late 1940s when I was trying to explain the role of the conservation authorities in a small Ontario city, a rabbi told a story from The Talmud. It seems two men were disputing the ownership of a tract of land but could not come to an agreement. They went to the rabbi and told him their claims. The rabbi said, "now let us go to the land to hear what it has to say". At the disputed parcel the rabbi listened and then said, "The land is saying, 'How can either man claim to own me, when, in reality, I own both of them?'".

We recognize the great privileges we have in being able to own land and to use it. We often forget the responsibilities of stewardship that ownership implies. We have every right to use the land but no right to destroy it. Our inherited forms of land ownership and the free enterprise system have specific constraints. While it is true we can use the resources we own in any way we wish there are specific limits to their use that are related to the rights of others. We can burn old tires but the smoke must fall back on our own property. We can plow up and down hill but the eroded soil must not go on our neighbor's land nor on or into the public lands and waters we all own. We can manufacture complex chemicals but the residues of the manufacturing must not pollute the air, soil, or waters that belong to others or to everyone. The principle is straightforward and honest. We can use the resources we own in any way we choose provided we do not infringe on the rights of others, individually or collectively.

The environmental challenge of the 1980's is related to water resources. What is our track record? In the early 1950's important meetings on water resources were held across our continent. One of the most important took place right here in the city where we are meeting today, Waterloo. It is safe to say that a quarter-century of constructive water management programs in Ontario derived directly from that meeting. The leadership of the Ontario Water Resources Commission, a direct outcome of the Waterloo meeting, developed hundreds of water supply systems and sewage treatment developments that have had profound health and economic benefits for Ontario. Point pollution was identified and dealt with. Perhaps we have become too complacent and have not kept up with the same rate of development characteristic of the early programs of the O.W.R.C. This summer of 1983, we have been shocked by the closing of beaches on Lakes Ontario, Erie, and Huron, as well as in many of the conservation authorities' lakes. What happened? Has the problem escalated beyond our technical capabilities to deal with it or have we become lax in our diligence.

London has a water supply system based on a pipeline system to Lake Huron. In many respects it is a "dream system". Yet this summer the single pipe burst and a water crisis threatened until the pipe was repaired. Should London have twinned the pipeline a decade ago? Should London have tied into the Lake Erie system that supplied Talbotville, only a few kilometres from London? The wisdom of maintaining stand-by wells in the London area proved to be important although are uneconomic and inefficient when the pipeline system is working. How much stand-by or "fail-safe" capacity should we but into our water supply systems?

In 1972, the United States of America and Canada signed a Water Quality Agreement that is of major importance to the Great Lakes region of North America. The agreement was updated and signed again in 1978. A new agreement, incorporating all the new information now available, is overdue. Neither country has moved to revise the agreement to deal with the conditions we face today. The International Joint Commission instituted the Pollution from Land Use Activities Reference Group (acronym: PLUARG) in 1975. Conscientious scientists and citizens on both sides of the line worked diligently to survey the problem and to make recommendations. These reports and recommendations, supported and passed on by the I.J.C., now sit on bureaucratic desks in Washington and Ottawa.

The importance of water as an environmental challenge can best be illustrated by recalling what happened in Vancouver in 1976. The United Nations Conference on HABITAT was planned to show what the future held for human settlement. Yet the only resolution on which there was full agreement was the one that stated in simple terms: "Everyone on earth must have access to clean water". There is consensus by all agencies involved that the major "third world" challenge is related to good water.

Yet, are we in the so-called developed "Northern World" in a strong position to tell anyone else what to do? Our track record is not very good. We have made a disaster areas of our groundwater resources on this continent. We have not handled our disposal problems in a civilized manner. Our practices do not keep up with our technological skills. We can do better than we do. Why don't we? As of 1983, we must heed the warning, "Every groundwater resource on this continent must be considered suspect". What an indictment and yet what a challenge to the scientist.

Reclamation, basically, means to put thing in such a way that use and enjoyment continues into the future. We might call what we are trying to achieve the civilized landscape. All uses are placed in their proper places and developed in such a way that they may be of continuing utility. The goal of regional planning is to recognize all the needs of man as they relate to his use of resources. All development programs should have concepts of redevelopment and reclamation built right into the basic plans and operations.

We have too many open systems in our resource use cycles. The ideal system is a completely closed cycle that we may never realize. We must, however, tighten up the cycle. "Cradle to the Grave" monitoring has been suggested as the appropriate practice for hazardous wastes management. Yet, the phrase is misleading. It implies that something can be buried. If we go back to the basic laws of thermodynamics we can assess the problem we face: the total energy content of the universe is constant and the total entropy is continually increasing. All of us must try to explain to others what this means. Every effort to do so is worthwhile. The Huron Erie Land Use Studies group (acronym: HELUS) is made up of retired scientists, engineers, executives, educators, etc. who put on seminars at the University of Western Ontario. HELUS is a good example of the conservation of professional skills. The next symposium will be held on Nov. 16, 1983 on the subject of "Municipal Solid Waste Disposal". The topic was suggested by provincial, municipal, and private sector organizations. The day's session will cover the provincial blueprint on waste management, the regional as well as the urban approach to the problem, and the role of the environmental assessment board. It will be an important day. The success of the HELUS group idea, which was founded in 1972 by the late Dr. James A. Vance of O.W.R.C. fame and one of the strong supporters of your association, should be studied carefully by other university and research centers. There is a valuable resource in "senior power" in the scientific and technological community. The senior group is able to support your efforts at the working edge of the professional skills you represent.

The current status of the electrical transmission expansion program of Ontario Hydro illustrates many of the complicated problems of resources planning. The Royal Commission of Electrical Power Planning (acronym: RCEPP) recommended, among other things that the nuclear power being developed at the Bruce generating centre must be brought to the upcoming shortage area of southwestern Ontario not only to serve the area but to maintain transfer capability with the North American power grid. Although the province, in a policy related to "slow-growth" areas, and the area involved wanted the facility at "the Bruce", the question of the transmission lines to get it out has created many interesting problems at both the plan and route stage. Many complicated problems must be analyzed and resolved. Many interesting situations must be reviewed and sorted out. I always find it interesting that the impact of the transmission lines on agricultural lands is given its justified high priority. Yet in the back of my mind I keep thinking that the most serious environmental alteration occurred when our great-grandfathers cleared the forests to make fields on which to grow crops. I am glad they did because, otherwise, I nor you would be here today.

There are many other problems we could discuss at length. All of them are important. As we develop a complicated agricultural-urban-industrial landscape, how do we preserve niches of the original environment so that we and our children can appreciate a full spectrum of our environmental heritage and treasures? What do we do about forests, wetlands, shorelines, geological things like escarpments, caves, and glacial features? The civilized challenge is wrapped up in the question, "What do we keep?".

In no part of North America is this question more important than in the urban-agricultural areas. Our cites should have tidy hems rather than ragged edges. Our cities should be practical examples of the conservation of variety. Cities grow in many ways: the edges which may sprawl, filling in spaces left over in "development", growing upward, and redevelopment. All of these may be managed wisely by the professional skills of those who advise the private-sector and governmental developers. Look about you to see the ways in which your professional skills are being used. Sometimes you are so busy you do not have time to look at what you have done and are doing.

I was asked to give a general talk but I feel I would lie to add something from the present work that may be useful. I am now convinced, with adequate evidence, that the so-called energy crisis has accelerated the centripetal forces over the centrifugal and the emphasis in urban development will be in greater concentration of urban elements. The "sprawl" has slowed and there will be more emphasis on lands already within the urban periphery such as lakeshore lands, railway lands, redevelopment, an even greater so-called gentrification, and reconversion of obsolete industrial lands to other urban uses. Economics will give us a new dimension to the established urban places.

You and I need to keep to a holistic framework in all that we do. Our day to day tasks are important but they must be seen as part of a larger fabric. We must remember that, as specialists in important fields, we must be able to connect with everyone else who is working in the same region or activity. We must always retain the important attribute of connectivity. In the Great Lakes region, the Great Lakes Tomorrow program on "Decisions" is emphasizing the "ecosystem" approach as recommended by the International Joint Commission. The Great Lakes Decisions program in 1983 focussed on Lake Erie with four universities in the United States and three in Canada participating. In 1984 the Decisions program will be based on Lake Ontario, the most endangered lake; in 1985 on Lake Huron; and in 1986 on Lake Superior. Yet, this year in the Erie Decisions program, many participants asked the question, "To understand the Ecosystem fully, is it not necessary to learn more about the works and minds of civilized human beings as they make decisions and do things?" This is an astute observation. It is difficult to categorize or give a description to this level of perception. In the London group we talked about such a concept as an Ergosystem (i.e. the works of man). We were not satisfied with our results. Perhaps you may help us. The idea that an Ergosystem concept would assist us in understanding and applying the Ecosystem concept was an unusual outcome of the Erie Decisions program.

You are professional specialists and as such have great responsibilities in the operation of the total environmental system. Isaiah Bowman, born in Waterloo County, was recognized as the Dean of American Geographers. The Environmental Studies Building here is named for him. I believe he best described the role you and I have in this challenging situation. He wrote, "The professional specialist must give leadership. He is able to view the board landscape of the problem at the same time he has dug some deep wells by his professional competence. He knows how things must be studied through his technical competence and he is able to apply his skills in understanding how everything works together as a system."

I wish to thank you for inviting me. I realize I am preaching to the converted. However, it is necessary for us to get together from time to time to share our experiences, our concerns, our successes, and especially our failures. It gets to be pretty lonely out there at times. I felt I was among friend as soon as I sat down to breakfast with you this morning.

NEW HORIZONS IN VEGETATION DEVELOPMENT

G. Michael Cooper
OSECO Farm Seed Centre
Division of OSECO Seed Inc.
Guelph, Ontario

It is with a great deal of pleasure that I address you this morning. My mandate here today, I guess, was to bring you up-to-date on what is happening with grass development, particularly as it relates to reclamation and other types of amenity grass situations; a presentation of the state of the art if you like and what's happening in our end of the industry in terms of development. Where we are going or at least where I see we are going and a broad picture of what we have done lately. I hope it won't be a disappointment but one of the first things I have to say is that the state of the art does not change very much in our business. I hope you did not come here today to get any new startling revelations on what might be happening in this industry because I am afraid there aren't any.

It is a rather plodding, slow reacting type of business primarily because we are most dependent on nature to do our developmental work for us.

One thing I would like to say, however, is that the area in which you work is one of the most fascinating parts of the grass development or seed industry, primarily because there is much potential for development. How quickly this development will take place will be very dependent on the need that is expressed.

On the down side of the situation, one of the things that we have to constantly battle in this industry is finding of a middle road between what really needs to be done, things that we should be doing and the cost involved in doing them. One of the things that you are always going to have to face in the reclamation field is the fact that there is no dollar return from the expenditure that is made. That is to say, it is always an afterthought, it is always, or at least almost always something that has to be done to fulfill some kind of legal or moral obligation. It therefore is not like a grain crop or corn crop where we can plant it, harvest it and expect to get a dollar value return from it. Most of the reclamation work done today is done because somebody else directed it. Quite often that direction comes from some kind of licensing authority or government department. As most of you are well aware a great deal of it goes out on tender, particularly highway mixes, roadside work and embankment work. Now one of two things happens on a tender, that is one or two things happen other than the fact that on a tender, the price is always low and with any low price comes low quality. The old scenario is, there are no free lunches, you only get what you pay for and all of the other cliches that go along to suggest that you cannot service an industry and expect to do it for no return. That is one of the things that tends to slow down the development in reclamation mixes and reclamation types of grasses. We are now beginning to work around it because the authorities and the people who are actually paying for reclamation mixes today are becoming more knowledgeable and more concerned about what is happening in the end; (the job that is really being done). One of the other problems in developing new products in this area is that there is such a very wide range of conditions. The development of materials then becomes relatively regionalized. As an example of this, we tend very much to use those grasses which we find somewhat exotic to this area in Eastern Canada while the Western folks have tended to stay with upgraded materials that are native to the area itself.

We have fallen behind the U.S., for instance in this area, because they have greater demand, even on a regional basis, for this kind of product. They also have a great concentration of use in a relatively small area, even within the regional confines of east versus west or north versus south. As an overview, I would say that I don't expect the industry will move at a much greater clip than it is today; nor I do not think it will as long as we are faced with having a "low ball" tender business in order to get volume.

Most of the work to date has been done in very confined, specific problem areas, for example, a particular problem with a very highly acid based land or to work with some particularly infertile areas with very little or no organic matter. So the greatest amount of development to date has come in those areas. This is all well and good but it does not cover the vast majority of areas - ditchbanks and roadsides and the kinds of things that are a fairly common type of problem.

Enough for that discussion, now I talk about some of the things that we are doing. Let us talk about some of the positive areas that we are kind of groping our way through if nothing else. I hope someday we will come up with the answers. We have been through a period of utilizing some of the tougher stemmed, deeper rooted legumes. The vetches, particularly crownvetch and trefoil, things of that nature are still being used to some extent. The drawbacks, however, in these products have outweighed the things that they were going to do for us. Crownvetch is, of course, very difficult to get established if there is any kind of competition (also true for trefoil). This makes it very difficult to ensure establishment, particularly in areas where you really do not want to have risk having to come back and it again.

If it is an aerial application or tough terrain in which it is very difficult to move vehicles, it becomes an expensive proposition to go in a second time. Therefore, we are tending to get away from those things as individual units. Vetch, of course, has the other problem of becoming kind of woody, entangled, a very unattractive colour in late fall and of course through the winter season, and as well as it is slow to recover in the spring.

The trend, today, is to mixtures and mixtures of very specific materials governed by the particular job that has to be done at the time. The way we are running seems to be almost, one might suggest, on a prescription basis. In general though, we are looking at some of the hardier, deeper rooted fescues and some of the new deeper rooted creeping fescues (some of them are now called spreading fescues). These are very attractive for this kind of work because of their root systems. Some of the hard fescues and the sheep's fescues which are tougher in nature than the creepers and certainly more upright, are also being used. They are being used either alone, depending on the aestethic situation and what you want the area to look like, or in combinations with trefoil or other legumes. White clovers, as an example, are used in some of these mixtures as a bottom material along with a little bit of trefoil. Generally speaking, these are put together in order to cover the spectrum of anticipated growing conditions. I think that we will always continue to try and include some legumes in the mixes. The purpose in these, of course, is to supply what they can in terms of nitrogen to provide for growth not only of the legumes but also of the grasses. One of our biggest problems of course, is that we are usually working on soils that are not particularly fertile or they do not have a high organic matter content, quite often they are not even soils. We are also going into areas that have problems other than growing problems or are specific problem areas; that is they are spill areas from chemicals or slag areas from mining operations. In other words, they do not contain anything other than a very basic or sometimes acidic formation which has been developed locally.

I have put together some slides and we will go through these pointing out some of the things that are being done, some of the specific locations that we have encountered recently and some of the unique problems that we encountered along with them. When you go through the slide program, there are undoubtedly are some interesting things that we are now considering.

We have here a gravel pit that is now a golf course. When you can put something like this back together it is a shining example to mankind, I guess, that you can replace at some cost something that is ugly, something that has become useless because it is finished; there is nothing more useless than a worked out gravel pit. There are ways of getting ones money back if people would start thinking in terms of what can be done with a piece of land to save it from erosion if it is put back into some kind of useable shape, even if it is strictly for recreational purposes. In the case of the golf course, one would have to suggest that over the years the owners probably will take as much money out of the golf course as they took out of the gravel pit and perhaps more because the golf course can go on for ever, probably subject only to urban pressure. Where this particular golf course is located, I do not think that urban pressure will be a problem in my lifetime.

Often the reuse of areas is recreational. It is a legitimate use of something that is worked out, or finished, or completed with little else to do with it. What else can you do with it? Well you can always make a park out of it, or a golf course, or something of that nature.

One of the other slides we looked at was the ski slopes in two different areas. One is a new piece of ski area, whereby utilizing landscaping and so on, somebody has been able to increase the ability to sell their own ski slope. The addition of more height and the way it is handled and put together is certainly a key in bringing people into that ski area.

The other ski area that we looked at of course, is a renovation, a re-doing. Probably something to keep it in competition with some of the others that are maybe a little steeper. They are putting in new runs and we are adding to the situation where, some of these reclamation mixes work in very well.

One of the things that we can all look forward to in this business is that, environmentally, pressure is on not to leave things as they were. To try and return them to some kind of shape where they can be useful or least can appear to be useful, I think, over the next five or six years probably going to put some emphasis on improving the routes we are taking in terms of reclamation and recreation type grasses.

I have talked here only about grasses, that being my background. I do not want to leave anybody with the impression that grasses are the answer to all erosion problems, or that they are the only things that you can use in terms of reclamation and renovation because they certainly are not. There are a great many applications where grasses are not the ideal route to follow.There are all kinds of ground cover mechanisms, naturally growing ones and some that are artificial. They are all part of the reclamation business. Please do not misunderstand, while it is my business, I am not particularly plugging grasses as the only answer. I think grasses work in well in a great many instances. It is a little difficult to plant myrtle on a ski slope. On the other hand, there are areas where one has to suggest that the steepness involved is probably such that erosion will not be held simply by grasses even if the root system is very deep and very strong. All of these things add up to good reclamation practices. All of them are viable in the areas in which they are designed to work.

I would like to leave you with one thought. Planning for reclamation (working in all of the factors) is really the key. I think this is where we have had most of the failure in the past. We have not really planned for reclamation. We have accepted some of the older methods without question, but we haven't spent a lot of time looking at some newer things and I think that this is the key to where we want to go from here.

I hope what I have said today has been of some use to you and that you can take it back and add it to your repertoires and your thought processes and maybe if I have changed some thought in the right direction then hopefully I have accomplished something.

I thank you very kindly for your attention today and perhaps we will talk more about this at a later date.

GREAT LAKES SHORE DYNAMICS, CONSEQUENCES AND PROTECTION

W.S. Haras
Bayfield Laboratory for Marine Science and Surveys
Department of Fisheries and Oceans
Canada Centre for Inland Waters
Burlington, Ontario

I have some difficulty, and even some apprehension, relating the happenings on the Canadian shores of the Great Lakes to the theme of this year's conference.

Planning - if there is any - is uncoordinated.
Practice - the only practice I can think of is malpractice, and
Results - disastrous.

Now that I've shocked you into paying attention, let's examine in more detail the problem of reclamation, or more appropriately, the problem of preserving one of our most precious natural resources - the shoreland of the Great Lakes.

The importance of the Great Lakes coastal zone to Canadians is unquestionable. One Canadian in three lives next to the Great Lakes, on which they are highly dependent for food, potable water, energy, industrial activity, settlements, transportation, and recreation. The Lake Ontario coastal zone alone contains about one-seventh of the Canadian population, and more than a quarter of the country's economic activity.

Since problems exist only where people exist, all problems ultimately relate to social needs and concerns, and problems associated with Great Lakes rehabilitation are no exception, and perhaps are more complex due to their inter-relationship and, more so, interdependence.

Problems such as toxic contaminants, shoreline industrial development, shore erosion/flooding, oil and chemical spills, loss of fishstocks/fishing opportunities, eutrophication/water pollution, agricultural runoffs, dredging, loss of habitats (wetlands), port and marina development, landfills, marina construction, lack of recreational access, transmission and transportation corridors, urban runoffs, thermal pollution (heated water) radioactive wastes, solid waste disposal, interference with littoral drift, urban water fowl and mineral extraction in that order of priority, are some indication of their complexity. Yet, to the majority of Canadians, these problems are remote and removed from day-to-day concerns. Is it because of their magnitude the Great Lakes have been taken for granted, in much the same way as the oceans? It is no wonder that often the Great Lakes are referred to as the inland seas. And why not? Their water surface area is larger than New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland combined, with the watershed the size of France and England put together. They hold almost twenty percent, or one-fifth of world fresh liquid surface water, or enough water to cover all of North America, to a depth of three feet.

It is a region so great that it includes two climate zones, three main types of forest, some of the most intensely cultivated, heavily populated and industrialized sections of the continent, and areas of wilderness that look much as they did before man arrived on earth.

Shore erosion and man's struggle to stop it is by no means new. Remains of early Mediterranean coastal villages have been found on the sea floor and records of ancient Italian fishing centres which, through erosion, were washed into the sea, are indisputable evidence of coastal recession. Today we have photographs and measurements of shore erosion which not only allow us to record, but to analyze the causes and processes involved in shoreline changes, enabling us to determine its temporal and spatial rate of retreat.

The loss of large amounts of land annually into the water of lakes represents a great financial loss to a country. Canada/Ontario Great Lakes Shore Damage Survey concluded in 1975 that "structural shore damage on Canadian shores of Great Lakes, due to erosion and inundation amounted to more than nineteen million dollars during the period of survey from November 1972 to November 1973. Combined with nine million dollars in lost land value due to erosion, total costs were in excess of twenty-eight million dollars. Immediate potential damage, which exists due to a combination of factors such as high erosion rates, proximity of buildings to edge of bank, or flood susceptibility, was estimated at an additional nineteen million dollars." Prof. Packer of the University of Western Ontario Geography Department has estimated about eleven years ago that $1.2 million in municipal assessment is lost each year because of erosion along Lake Erie shore. The reclaiming of residential land and valuable farmland that has eroded away is a very difficult and costly task. Quoting again from the Technical Report of the Canada/Ontario Great Lakes Shore Damage Survey, "The survey demonstrated regional variance in the extent of property damage and intensity of shore erosion and was used to delineate hazard lands. The estimated cost of longterm protection in these hazard lands was $1.02 billion, or $287/m, while total property value was estimated at $1.3 billion, or $364/m, (using the 1973 dollars). It should also be noted that 54% of the total 'hazard land' shoreline is presently worth less than the cost of longterm shore protection."

What then? If we listen to the economists we would flee to higher ground, or stay and do nothing, as many riparian owners, including governments, who are also riparian owners, did - mostly the latter! Is that a solution? In many instances it is a cop-out, a failure! Man is not entirely innocent in the erosion process. He has accelerated this wear on land forms by clearing land of protective vegetation, and building roads and other structures perilously close to the shoreline. This practice was understandable during the days of the first settlers, but inexcusable today, when a wealth of information is available just for the asking. Today we should be aware of why and what is happening to our natural resources, in this case the Great Lakes and its' shore. But are we? Aristotle knew in 300 B.C. when he said that "nature does nothing without purpose." Da Vinci knew in 1500, stating "nature never breaks her own laws."

- We knew in 1952 when the Ontario Select Committee on G.L.W.L. published a report on high water levels and associated damages and erosion along the Great Lakes shoreline.

- We knew in 1954 when the fury of hurricane "Hazel" played havoc on the shores of Lake Ontario.

- We knew in 1975 when Canada/Ontario governments published the results of a survey of the Great Lakes shore damage, caused again by high water levels and storm activity in the spring of '73.

- We know now, ten years later, when the headlines in the press and the interest of politicians waned, that the same shores are continuing their erosional process - but do we want to find out why and what triggers the process? Seldom. The majority of us are no better than the politicians or the press - we are only prodded to action by a crisis! Why do we lock the barn door after the horse has been stolen? Is human nature so hard to change? Or are we too complacent? Or perhaps the message is not reaching the audience. We must realize that there are only so many miles of shoreline and no more. We must understand how to preserve what we've got. We must understand, in general terms at least, what initiates the erosion. To know it is a natural, but complex process of disintegration or weathering which tends to alter and destroy shore banks and structures on them when exposed to the natural forces of wave action, ground water seepage, frost and ice action, rain and surface runoff, and also that of the wind, is not enough.

To know that erosion begins by the transfer of kinetic energy from water or air to the shore materials, dislodging the unconsolidated materials and transporting them to other areas sounds simple enough. However, in examining the factors involved in dislodging shore material, the major consideration is the strength or resistance to dislodgement of the material, with relation to the intensity and nature of the energy-related forces brought to bear upon it. In other words, for erosion to result, the material comprising the shoreline must be erodible under the particular energy conditions to which it is exposed, namely water and air.

Furthermore, the amount of material removed from a section of shoreline depends on background factors inherent in the lacustrine environment of the Great Lakes, such as non-tidal fluctuations in water level, physical characteristics of the shoreline, supply of littoral materials, and wave climate. If these factors were constant and unchanging, a point would have been reached when erosion would cease and a stable shore would be established. That this is not the case must be due primarily to changes and trends related to those background factors. Such changes could occur either naturally or as a result of human activities. An analysis of these factors indicates that the natural factors such as climatological and physical characteristics have the greatest significance. The effects of man-induced factors such as water level regulations and construction are usually of a lesser magnitude. They may, however, be accentuated by the unpredictability of the natural factors. Thus, in order to deal with shore erosion our knowledge of natural factors must be expanded to increase our predictive capabilities and better chance of mitigating the extent of the erosion problem. By building protection that will cooperate with nature instead of opposing her, we may have the best and lasting results.

There is no stereotype method of shore protection which might be applied to all sections of shoreline, or even to all locations within any one section. Each of the different types has their own advantages, disadvantages and limitations, and these attributes generally dictate the method and degree of protection to be employed.

The best of all methods is the one that is built by nature - the beach. In order for a beach to be an effective protection for the backshore, a sufficient amount of detrital material must be supplied either naturally, by littoral drift, or artificially by bringing in new sand from a nearby source, using mechanical methods, to provide a stable beach slope of approximately 1:30 or flatter. When the shore natural processes responsible for beach development are in adjustment and sand and gravel are being replenished as rapidly as material is being carried away, then a dynamic equilibrium is created. This mainly depends on the relationship of four factors: waves, lake level rise, beach sand and shape of the beach. The natural balance between these factors is what maintains a stable beach, which, it should be remembered, consists not only of the dry, visible portion, but which also extends offshore to a depth of 15 to 20 metres, forming a first line of defense, dissipating the energy of breaking waves.

In some instances, however, nature is totally impassive. In such cases she must be prodded to act in a manner which is beneficial to man. The best example of such cooperative action is the groyne, a wall-like structure built perpendicularly from the shore. Usually constructed in groups, rather than as isolated units, they are called groyne fields or systems. Their primary purpose is to trap and retain sand, and modify offshore currents and wave action, nourishing the beach between them. When a well-designed groyne field fills to capacity with sand, longshore transport of sand continues at about the same rate as before the groynes were built, maintaining a stable beach. Groynes are the most widely used shore protective measure and are suitable where a beach is desirable.

In other instances nature acts in a hostile manner toward man. Then engineering methods should be the choice. Seawalls and bulkheads are the primary examples of such methods. These are retaining walls built parallel to shore, protecting the land behind them and are constructed to withstand the heaviest damage by waves and ice. They are out of necessity massive and expensive and, because of their high cost they would be limited to highly-developed areas where it is essential to hold a fixed line, or where other shore protective measures are not feasible. These structures are not benefitting the shore in front of them, since much of the energy of the waves breaking on them is redirected downward to the toe of the wall, causing the scour and accelerated erosion of the beach.

A similar function to seawalls and bulkheads is performed by revetments. This is a sloped facing, usually of stone or concrete, used to sustain an embankment, and to protect against storm wave action. Most revetments do not redirect wave energy and do not interfere with littoral drift, as their function is to absorb the energy of onrushing waves rather than repel them.

A structure built offshore and usually parallel to it to "break" the incoming waves, thus dissipating their energy, is called a breakwater. It serves a dual purpose, by first preventing the destructive waves from reaching the shore, and secondly creating a sheltered area for boat mooring, or safe entrances to harbours.

Many other devices in various combinations of basic designs aforementioned, varying only in size and material, are used. All of them are mainly concerned with protection of the shore to the extent of one's imagination and financial limitation. Nevertheless, this type of solution seldom achieves the desired results, especially when a long-lasting protection is anticipated - instead, disappointment and frustration takes place, which eventually leads to neglect and abandonment of shore property.

In using all of these protective methods, it should be borne in mind that individually we have a losing battle on our hands, and only by a joint effort, designed not only for a group of properties, but for the entire reach of shore, or even the whole lake, can we feel secure and look forward to a well-managed and planned community on the waterfront.

SESSION II-A

PLANNING

Dr. H.P. Sims - Chairman

A PRACTICAL METHODOLOGY FOR THE ASSESSMENT AND CLASSIFICATION OF ABANDONED MINERAL RESOURCE EXTRACTION SITES RELATIVE TO THE NEED FOR THEIR REHABILITION

By: D. Walmsley, (Env. Geologist-Planner)
Planning Department
Regional Municipality of Peel

ABSTRACT

In respnse to policies contained in the proposed Aggregates Act Regional Planning staff, in cooperation with staff from the Ministry of Natural Resources and the Region's three member municipalities, have developed a method of assessing and classifying abandoned mineral resource extraction sites relative to the need for their rehabilitation. Under the terms of the proposed legislation the Ministry of Natural Resources, in consultation with Regions, Counties and local municipalities, will determine which sites should receive funding for rehabilitation work. Municipalities will play a key role in this process so it is important that they know the location and condition of abandoned pits and quarries within their areas of jurisdication.

The site classification methodology, developed by Regional staff, is based on two major criteria. These are, visual impact and the hazard a site may pose to the general public. The visual impact criterion is defined by the visibility of a site and the land use(s) to which a site is visible. The hazard a site poses is defined on the basis of its physical characteristics, accessibility and the land use(s) to which it is accessible.

After the location of all sites has been established, each is screened relative to whether it has been rehabilitated or has naturally revegetated. The sites which pass through this screening process are then ranked relative to their visual impact and hazard, through the use of a series of matrices. Final classification of each site is obtained by comparing its visual impact ranking with its hazard ranking.

The Government of Ontario will be providing funds to be used for the rehabilitiation of abandoned mineral resource extraction sites. Regions, counties and local municipalities will be responsible for advising the

Government on which sites within their boundaries are in most need of rehabilitation. The methodology developed by Regional staff will allow municipalities to carry out this responsibility by providing a tool with which they may effectively assess abondoned sites.

INTRODUCTION

The past decade has seen an increasing amount of interest, by the Ontario Government and Municipalities, in making active (licensed) pit and quarry operations more compatible with surrounding land uses. The Pits and Quarries Control Act, passed in 1971, was the first major attempt by the Ontario Government to achieve this. In 1975, the Ontario Mineral Aggregate Working Party was established by the Minister of Natural Resources to examine various shortcomings in this legislation. One of these shortcomings was that the Act did not address the problems associated with pits and quarries abondoned prior to its implementation.

People have, for the most part, learned to live with these sites. Many abondoned pits and quarries have been reclaimed either through urban expansion or individual initiative while others have become revegetated naturally. There are still a large number of sites which pose a hazard to the general public or which are visible to homes and recreation areas.

The Ontario Minister of Natural Resources has drafted a new more comprehensive piece of legislation, in response to the report of the Mineral Aggregate Working Party, known as the Aggregates Act. This draft legislation recognizes the need to reclaim abondoned pits and quarries by proposing to establish a fund, generated from the annual licence fee paid by active operations, which will help pay for their rehabilitation. Under the terms of the proposed legislation the Ministry of Natural Resources, in consultation with Regions, Counties and local municipalities, will determine which sites are in most need of rehabilitation.

DISCUSSION

For the purposes of the study, Peel Planning staff have defined an abondoned pit or quarry as a site which is not licensed under the Pits and Quarries Control Act, 1971 where the extraction of earth material is recognized to have occurred at some time in the past and which has not been reclaimed.

The Criteria

Site classification is based on two major criteria. These are, visual impact and the hazard a site may pose to the general public.

The visual impact criterion consists of two components:

(1) The visibility of the site; and
(2) the surrounding land use(s) to which the site is visible.

Surrounding land uses are divided into two categories, based generally on the number of people associated with them.

Category 1 - greater than 5 lots (urban residential, plan of subdivision, etc.)
- Recreation Areas
- Provincial Highways

Category 2 - less than 5 lots (urban residential, plan of subdivision, etc.)
- Regional Roads
- Local Roads

Site visibility is defined in terms of three conditions:

(1) visible
(2) partially visible
(3) screened

A site is visible if greater than 50% of its area can be seen from an identified land use. A site is partially visible if less than 50% of its disturbed area can be seen from an identified land use. Partial or complete screening of a site may be provided by the orientation of former extraction faces, the local topography and/or the extent of vegetation cover in the vicinity of the site. If a lot is less than or equal to 15 acres in size, then the following applies:

- with a house - site visibility is determined from the structure and the immediate area;

- without a house - site visibility is determined from anywhere on the lot.

If a lot is greater than 15 acres in size, site visibility is determined only from a house and its immediate area.

Site hazard is also defined on the basis of three conditions, there are:

(1) site condition (determined by is physical characteristics);
(2) site accessibility; and
(3) the land use(s) to which the site is accessible.

Site Condition is determined on the basis of the presence of hazardous slopes, on-site debris, and on-site ponds.

Hazardous slopes are defined on the basis of their grade and height. If a slope has a grade of greater than or equal to 1:1, combined with a height of greater than 3 metres, it is considered to be hazardous. Both slope, grade and height may be determined using various photogrammetric techniques. If the grade and height of the slopes in an abondoned site vary appreciably, the highest and steepest slopes are used to classify the site. Additional factors such as vegetation cover and the presence of instability features, such as rills and gullies, are interpreted and recorded for future reference. The presence of on-site debris is fairly easily identified using aerial photographs although field checks may be required for a final interpretation. On-site debris may vary from discarded houshold items to abandoned buildings. On-site ponds are considered to be a hazard only if found at the base of a hazardous slope. Additional field work may be required to determine whether the standing water is ephemeral or permanent.

Site Accessibility is defined in terms of 2 components. A site is either accessible to an identified land use or it isn't. The accessibility of a site is a function of a number of conditions that are specific to that particular site. As a result, accessibility must be interpreted on a site-specific basis. There are, though, a number of factors which aid in the interpretation process, these are as follows:

- if a site is located adjacent to an identified land use, it is accessible;

- if there is a laneway or trail leading from an identified land use to a site, it is accessible;
- if there is evidence that the site is being used for various activities, such as trail bike riding, it is accessible; and,
- if there are no natural or large man-made obstacles between a site and an identified land use, the site is accessible.

The Methodology

Site classification consists of three operations, there are:

(1) Site Inventory;
(2) Site Assessment;
(3) Site Classification, (Figure 1)

(1) Site Inventory - All relevant data sources are researched to determine the location and identity (pit or quarry) of former extraction sites. These include published geological and mineral source reports and maps, former official plans and planning reports. Each site is identified as either a pit or quarry and plotted on a 1:50 000 scale base map.

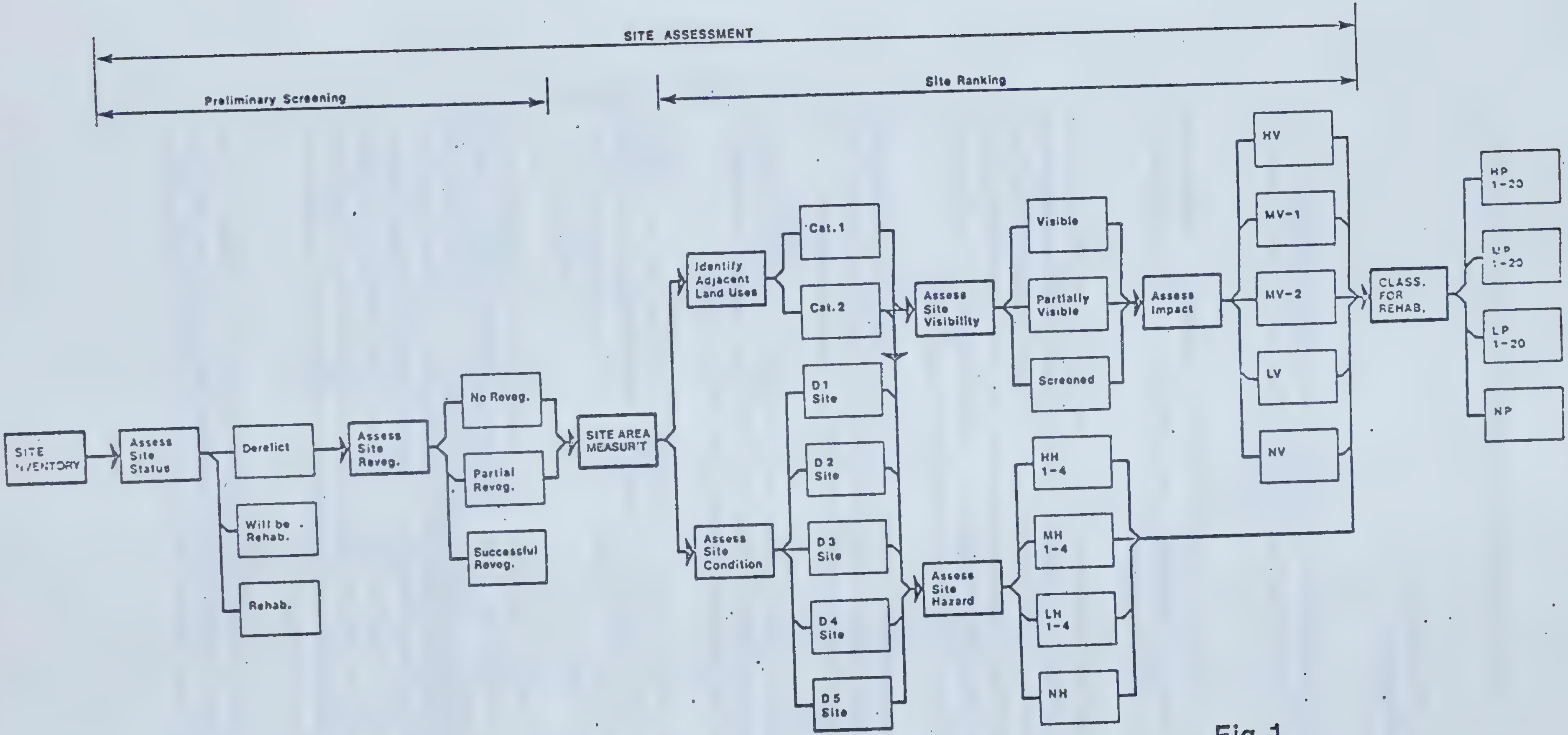

SITE ASSESSMENT
Preliminary Screening
Site Ranking
SITE INVENTORY
Assess Site Status
Derelict
Will be Rehab.
Rehab.
Assess Site Reveg.
No Reveg.
Partial Reveg.
Successful Reveg.
SITE AREA MEASUR'T
Identify Adjacent Land Uses
Assess Site Condition
Cat.1
Cat.2
D1 Site
D2 Site
D3 Site
D4 Site
D5 Site
Assess Site Visibility
Assess Site Hazard
Visible
Partially Visible
Screened
HH 1-4
MH 1-4
LH 1-4
NH
Assess Impact
HV
MV-1
MV-2
LV
NV
CLASS. FOR REHAB.
HP 1-20
MP 1-20
LP 1-20
NP

Fig.1

METHODOLOGY FOR THE ASSESSMENT AND CLASSIFICATION OF ABANDONED MINERAL EXTRACTION SITES

REGION OF PEEL PLANNING DEPT., PLANNING POLICY SECTION, JULY 1983.

(2) Site Assessment - This operation consists of three components, there are:

a) Preliminary Screening;
b) Area Measurement;
c) Site Ranking·

(NOTE: Site Assessment is carried out mainly through the use of aerial photographs, supplemented with field work if necessary.)

a) Preliminary Screening - Each site is screened to determine whether it warrants further consideration. This process is broken down into two parts.

- Site Status Assessment - If a site has been rehabilitated or is located on land for which there is a commitment for future development, it is not assessed further. Commitments for development include secondary plans passed by the respective municipality or plans of subdivision that are at least draft approved.

- Site Revegetation Assessment - If a site has undergone successful natural revegetation, i.e. 100% of its area is covered, it is dropped from further consideration.

b) Site Area Measurement - The area of each remaining site is measured and recorded. Measurements are taken from aerial photographs using either a planimeter or dot grid.

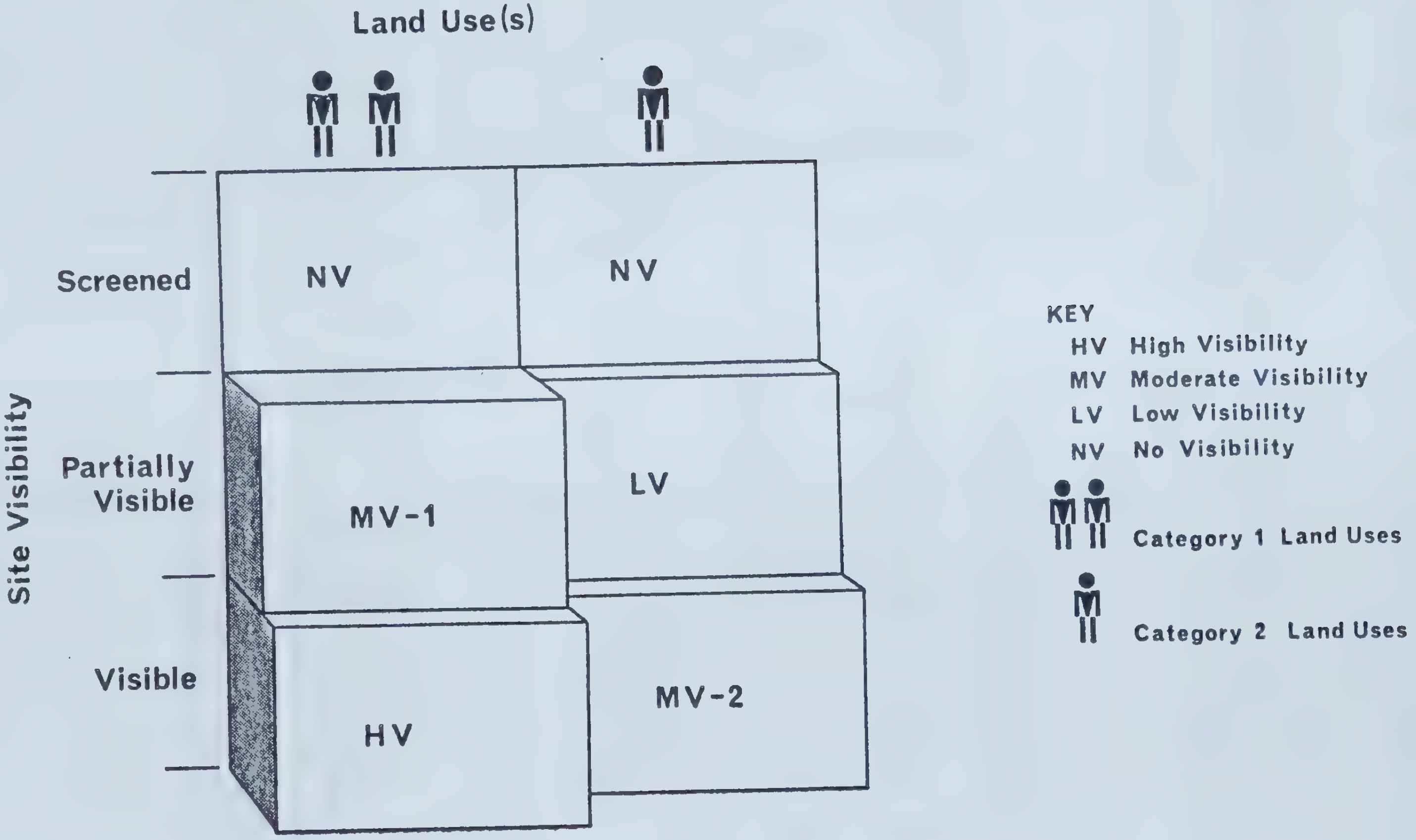
c) Site Ranking - Each site is ranked relative to its visual impact and the hazard it poses to surrounding land uses. (These operations may be carried out simultaneously as illustrated in Figure 1.)

Ranking of Visual Impact - the visual impact of a site is ranked by comparing its visibility characteristics with identified land uses. This is accomplished by first identifying and categorizing surrounding land uses, then determining the sites visibility characteristics. Visual impact is then ranked using the matrix illustrated in Figure 2. A site may exhibit high, medium, low and no visibility characteristics. Each site can only be placed into one category so ranking is carried out on a "worst-case" basis.

Ranking of Site Hazard - The hazard each site poses to the general public is ranked by comparing its condition with its accessibility from identified land uses. This is accomplished

Fig. 2

VISUAL IMPACT (Site Ranking)



Land Use(s)
Site Visibility
Screened
Partially Visible
Visible
NV
NV
MV-1
LV
HV
MV-2
KEY
HV High Visibility
MV Moderate Visibility
LV Low Visibility
NV No Visibility
Category 1 Land Uses
Category 2 Land Uses

by first assessing and ranking the condition of the site (Figure 3). After the site is ranked based on its physical condition, its accessibility to identified land uses is assessed and the hazard that the site poses is ranked using the matrix illustrated in Figure 4.

(3) Site Classification - The final classification of each site, relative to the need for its rehabilitation, is achieved by comparing its visual impact ranking with its hazard ranking using the matrix illustrated in Figure 5.

Fig. 3

SITE HAZARD (Rank Site Condition)

IF:	**A, B&C**	**D1 Site (Most Danger)**
	A, B/A, C	**D2 Site**
	A	**D3 Site**
	B	**D4 Site**
	C	**D5 Site (No Danger)**

KEY:

A - Hazardous Slopes
B - On Site Debris
C - On Site Ponds

CONCLUSION

The Government of Ontario will be providing funds to be used for the rehabilitation of abandoned pits and quarries. Regions, Counties and local municipalities will be responsible for advising the Government on which sites within their boundaries are in most need of rehabilitation. The methodology, described in this paper, will allow municipalities to effectively carry out this responsibility by providing a tool with which they may objectively assess abandoned sites.

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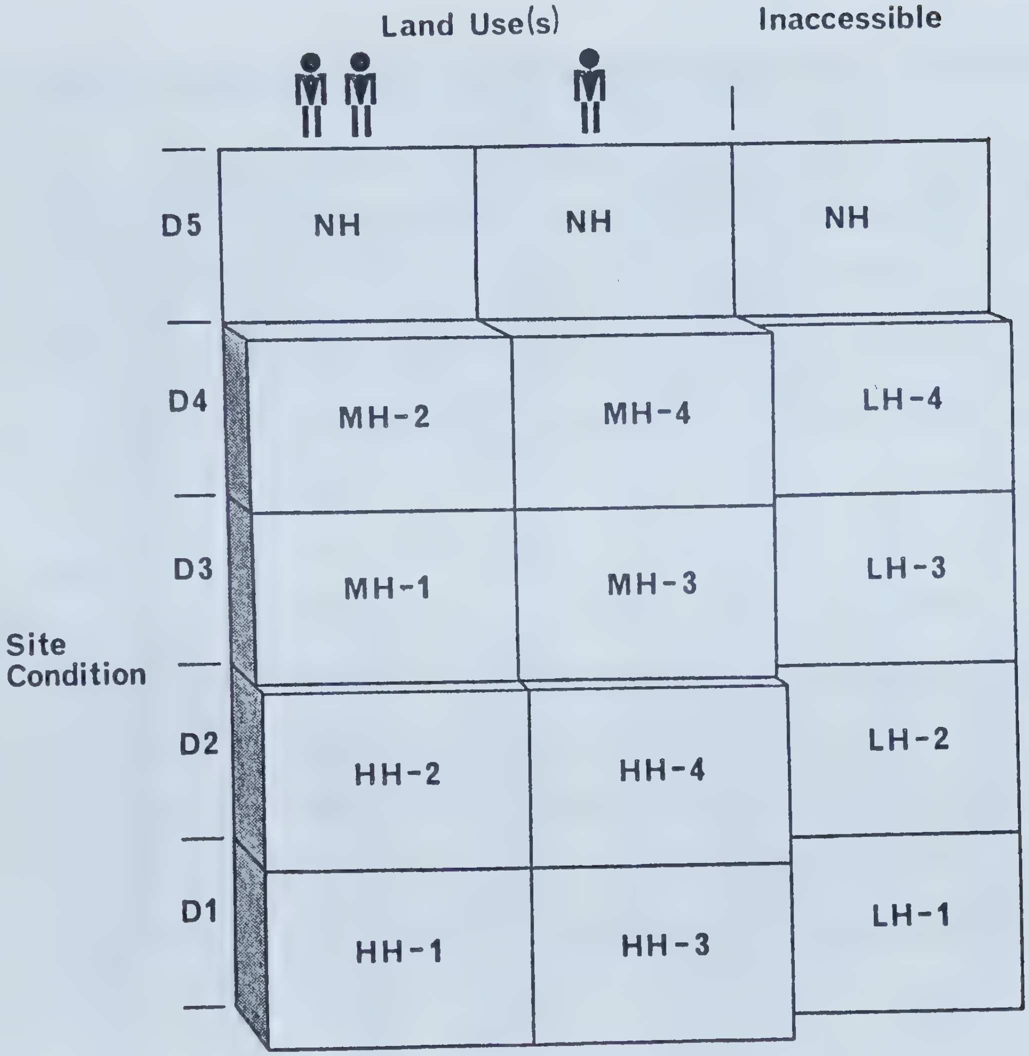
SITE HAZARD (Rank Site Hazard)


Land Use(s)
Inaccessible
Site Condition
D5
D4
D3
D2
D1
NH
NH
NH
MH-2
MH-4
LH-4
MH-1
MH-3
LH-3
HH-2
HH-4
LH-2
HH-1
HH-3
LH-1

KEY

HH High Hazard

MH Moderate Hazard

LH Low Hazard

NH No Hazard

NOTE: Numerals within matrix represent priority ranking within each category

Fig. 5

FINAL SITE CLASSIFICATION

Site Hazard		Visual Impact					
		H.V.	M.V.-1	M.V.-2	L.V.	N.V.	
N H		61	62	63	64	65	No Priority
L H	4	56	57	58	59	60	Low Priority
	3	51	52	53	54	55	
	2	46	47	48	49	50	
	1	41	42	43	44	45	
M H	4	36	37	38	39	40	Moderate Priority
	3	31	32	33	34	35	
	2	26	27	28	29	30	
	1	21	22	23	24	25	
H H	4	16	17	18	19	20	High Priority
	3	11	12	13	14	15	
	2	6	7	8	9	10	
	1	1	2	3	4	5	

NOTE: Numerals within matrix represent priority ranking within each category

MODELLING AND MONITORING - REGULATORY CONTROL OF SURFACE MINE REHABILITATION

A.G. McLellan
Department of Geography
University of Waterloo
Waterloo, Ontario

P. Cutmore
Ministry of Natural Resources
Maple, Ontario

INTRODUCTION

As the Canadian economy expanded in the 1960s and early 1970s, so also did the demand for sand and gravel, crushed rock, shale and other construction materials. The offensive social and environmental impacts of surface mining (in Ontario mainly pits and quarries) and consequent public concern resulted in Provincial Government intervention through the imposition of the Pits and Quarries Control Act in 1971.[1]

Despite this action, municipalities, organized groups, private citizens and even the Provincial Government have not felt that the act has fully achieved its goals. The government took the initiative of establishing:

(1) a major, broadly representative, (public, municipal, conservation, government agency and industry) committee to investigate the inadequacies and suggest solutions;[2]

(2) stimulated research into problem areas viz. abandoned pits and quarries,[3] rural and urban rehabilitation,[4] tree and shrub uses in rehabilitation;[6]

(3) more economic issues such as demand and accessible resource projections and transportation issues[7] were not forgotten.

Changes in the government regulations have been part of this evaluation and the experience of the past decade will result in a newly drafted Agrgregates Act due to replace the earlier legislation in the near future.[8]

The early legislation, through regulatory and monetary controls and through site plans emphasizing topsoil handling, land regrading and vegetation reinstatement, attempted to promote rehabilitation. That this goal was not achieved was acknowledged by government[2] and is the result of its removal. During the 1970s government and industry became more aware of these faults and an elaborate approvals process was established which insured increasing sophistication.

Rehabilitation plans became more realistic with an extraction process more suitable to the site, and an after use more suited to the surrounding municipal land use designations. Improvement of the rehabilitation concepts in the site plan was paralleled by a greater understanding of technological practice and what constitutes effective rehabilitation. While recent reports indicate up to two-thirds of all mining sites show evidence of rehabilitation[4] other important questions remain unanswered and probably dominant in the public mind -- why do one-third of all aggregate operations still after 10 years show no land rehabilitation? Why is progressive rehabilitation not standard practice? -- How do crop returns on rehabilitated land compare with pre-mining yields? -- Why do large proportions of the property remain as unsightly eye sores without speedy restitution to productive ability? -- all very good questions.

Recent Activity in Ontario

More recently several recommendations have been made in order to initiate a more successful rehabilitation program.

The rehabilitation program required a licenced operator to submit a levy of two cents per ton of aggregate material extracted, which was held in a security account and returned upon completion of rehabilitation work. The two cents per ton levy was simply viewed as "one more tax" by many operators and has proven inadequate due to escalating cost of equipment and rehabilitation measures and because most of the funds were easily expended in peripheral cosmetic work which did not constitute effective rehabilitation. The levy was increased to eight cents per tonne in 1981, in order to represent a more realistic rehabilitation cost of disturbed land and encourage better performance rates of rehabilitation.

Initial concepts of rehabilitation in Ontario appear to have evolved from an indefinite but simple understanding which later became a more complex issue. Much of the efforts of the regulatory Ministry in the first several years were absorbed in explaining and interpreting the Pits and Quarries Control Act and redefining objectives and policies.

As the level of security funds increased in the rehabilitation accounts and the regulatory requirements took effect on licenced operators, the concept of rehabilitation continued to evolve. In Ontario it is today generally agreed that rehabilitation should aim at the speedy restoration of land to a condition where it can fulfill a socially acceptable function, whether it be urban, rural or recreationally oriented land uses. By this criterion over one-half of the total amount of security funds granted in the 1970s may have been expended is cosmetic but noneffective rehabilitation measures.

Tables 1 and 2 show the changes in "acceptable rehabilitation" as measured by government approval practice.

With increased experience and research concerning the concept and procedures of rehabilitation a third period of "rehabilitation" expectation evolved. Table 3 illustrates the relative percentage of rehabilitation conducted on disturbed land in seven municipal areas in Southern Ontario. On average, less than 10 percent of the total disturbed land area had been rehabilitated by 1982. These rates are similar in value, irrespective of municipality area or geographic location. The percentage rates are low in value, due to the relative low security fund previously levied and the ways in which these funds were applied by operators. Because the Ministry is now - in the 1980s withholding security deposits (minimum of $1,000/hectare and maximum of $3,000 where operators seem less cooperative) the situation will undoubtedly improve over the next few years.

The remainder of this paper is concerned with the development of a just, effective policy concerning how progressive rehabilitation should be implemented in Ontario in the future. It is concerned with ensuring that government standards are obtainable, economically sound, rationally monitored and uniformly applied throughout the different administration districts of the Province of Ontario. It also is concerned with assuring that aggregate producers have a clear set of goals to implement.

PART II

Upgrading Rehabilitation Performance Through Model Guidelines

Both financial and educational models are presently being used to stimulate improved rehabilitation results. An examination of three primary approaches will prove reasonably comprehensive.

"Government Financial Security Model"

The first and most important is found in the Pits and Quarries Control Act through the establishment of a security fund for each licenced property. The financial system requires the per tonne levy (increased from 2 cents per ton to 8 cents per metric tonne in 1981 to reflect rehabilitation costs more realistically) to be held in an account until rehabilitation is completed. A minimal amount level ($1,000 per disturbed hectare) is retained in the account until the property is completely rehabilitated, the maximum amount level is $3,000. The security fund system provides for an annual refund to the operator in compensation for rehabilitation work if approved by a government inspector. Recent personal experience suggests encouraging improvements in rehabilitation rates.

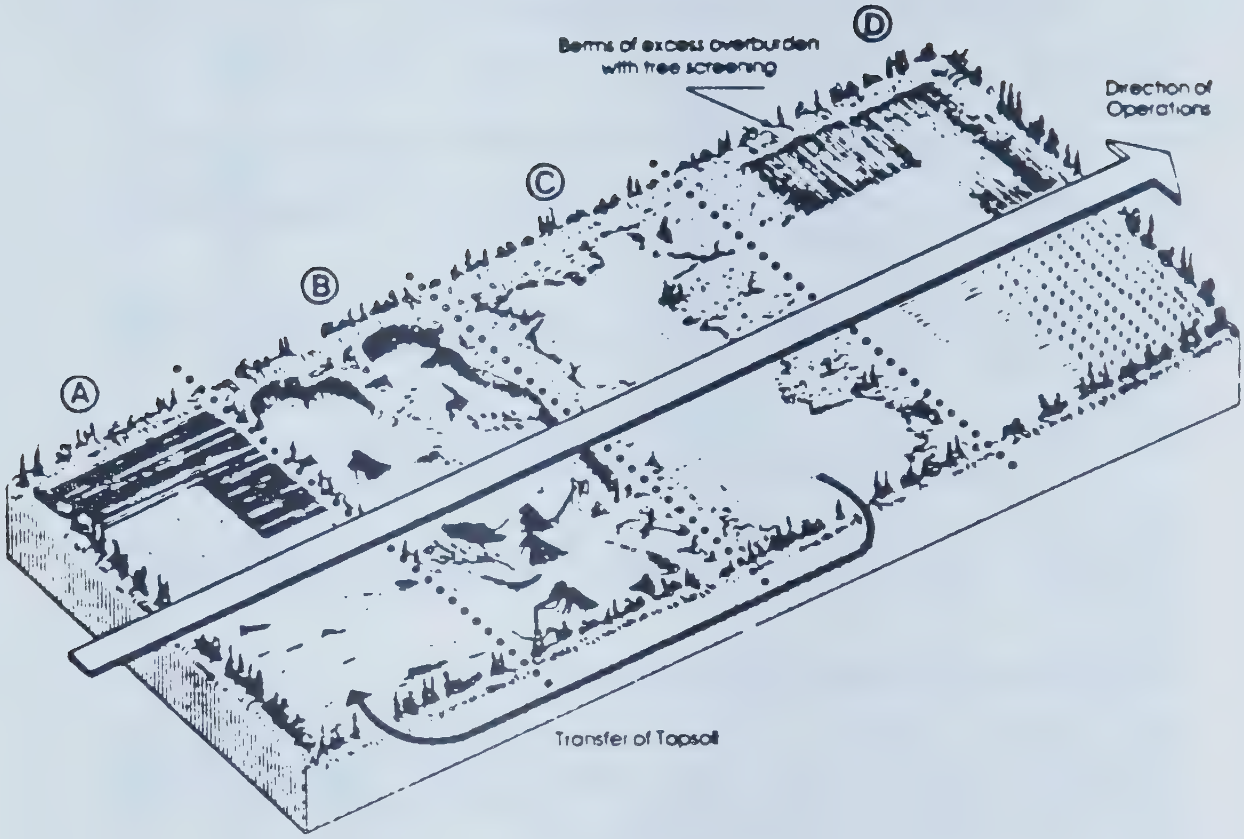
"Standard Rehabilitation Model"

In the above and early rehabilitation experience the basic elements missing were the establishment of clear goals, conceptual and comprehensive planning and a flow pattern which could link the various rehabilitation procedures together. Expensive rehandling of topsoil and overburden and costly errors of judgment in the industry were common. In 1975, McLellan portrayed the Standard Rehabilitation Model as shown in Figure 1, land was considered as in one of four conditions vis:

(1) land containing untouched reserved and remaining in the previous land use activity;

(2) land containing untouched reserves but being prepared for extraction activity;

(3) land containing the actual mining and processing activities; and


Ⓓ
Berms of excess overburden with tree screening
Direction of Operations
Ⓒ
Ⓑ
Ⓐ
Transfer of Topsoil

A DIAGRAM OF PIT OR QUARRY REHABILITATION

A. Land under rehabilitation
B. Current extraction area
C. Area stripped of overburden
D. Land still in agricultural use

Figure 1. McLellan's standard rehabilitation model. (From McLellan, A.G., 1979. Phased Rehabilitation System Guidelines Proposed. "Interface," Aggregate Producers Association of Ontario No. 2, June 1979, p.3.)

(4) land which having passed through the previous three conditions is now returned or being returned to the original land use through rehabilitation.

Important concepts in this model are that:

(1) the mining activity is only an interim use of the land;

(2) that the process should proceed in a progressive and sequential manner;

(3) that the combined area of Categories B and C should represent the smallest possible fraction of the total land parcel; and

(4) that the maximum area of land should always be available for the alternative (in this case, agriculture) land uses.

The attempt was meant to induce operators to follow a cost effective, stream-lined, publicly acceptable rehabilitation approach.

"Agricultural Technical Staging Model"

With further research and experience, MacIntosh and Moxuraitis (1982) have added greater understanding about implementation to the techniques of agricultural rehabilitation. The main elements incorporated into the model are:

(1) adequate pre-planning of the operation, with allowance for flexibility with plan modification;

(2) removal of an appropriate area of overburden, for up to 3 years extraction depending on size of operation; the storing of topsoil and subsoil separately, with the minimum of rehandling; and

(3) emphasis on techniques which guarantee the speedy return to maximum agricultural productivity with minimum subsequent corrective work.

The model at the site level adds to the concepts of the previous model to further minimize the negative impacts of the mining industry on the Province's agricultural base (see Figure 2).[9]

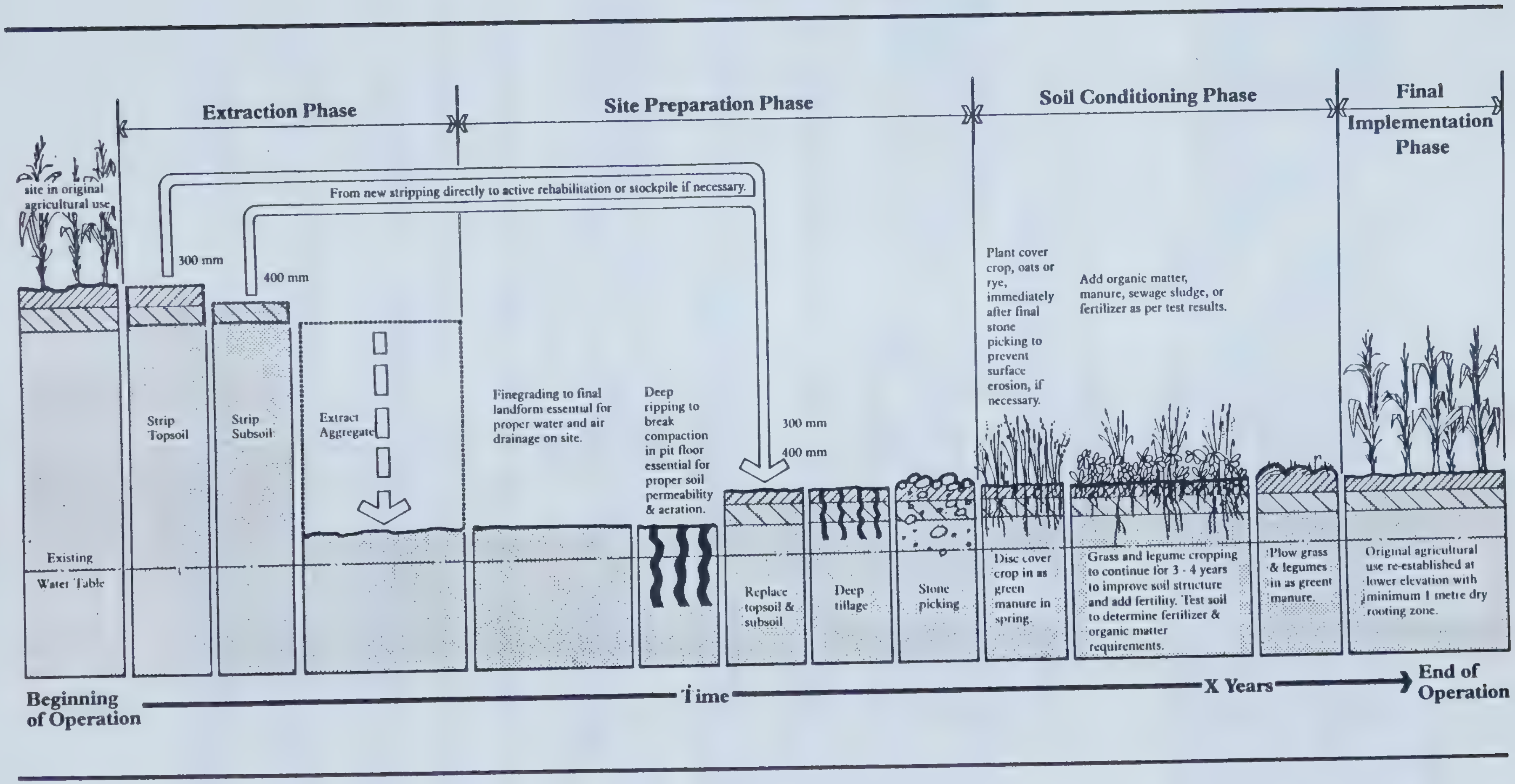

Extraction Phase
Site Preparation Phase
Soil Conditioning Phase
Final Implementation Phase
site in original agricultural use
From new stripping directly to active rehabilitation or stockpile if necessary.
300 mm
400 mm
Strip Topsoil
Strip Subsoil
Extract Aggregate
Existing Water Table
Finegrading to final landform essential for proper water and air drainage on site.
Deep ripping to break compaction in pit floor essential for proper soil permeability & aeration.
300 mm
400 mm
Replace topsoil & subsoil
Deep tillage
Stone picking
Plant cover crop, oats or rye, immediately after final stone picking to prevent surface erosion, if necessary.
Add organic matter, manure, sewage sludge, or fertilizer as per test results.
Disc cover crop in as green manure in spring.
Grass and legume cropping to continue for 3 - 4 years to improve soil structure and add fertility. Test soil to determine fertilizer & organic matter requirements.
Plow grass & legumes in as green manure.
Original agricultural use re-established at lower elevation with minimum 1 metre dry rooting zone.
Beginning of Operation
Time
X Years
End of Operation

Figure 2. Progressive rehabilitation sequence for restoration to an agricultural after-use. (From Mackintosh, E.E. and E.J. Mozuraitis, 1982.)

Evaluation

The major omission perceived in present practice is the absence of performance guidelines which control the aerial disturbance of an operation. Neither aggregate operators, nor government inspectors and especially not the public, have any clear understanding of how much rehabilitation, should take place, where and by when, and this constitutes an omission leading to misunderstanding and conflict. It is for these reasons that we offer the suggestions in the subsequent section.

PART III

A Rehabilitation Performance Model

The Ontario government which plans to proceed with the Aggregates Act within the next year will continue to require operators to complete rehabilitation returns on an annual basis. In preparation for this task, an evaluation program should be formed to adequately assess:

(1) the amount of disturbed land that should exist on a licenced property; and

(2) the amount and rate of rehabilitation that should be conducted on the same licenced property.

The goals of current and future government aspirations are displayed in what we call "Rehabilitation Time/Performance Model" (see Figure 3). This model consists of three time-related phases:

(1) Phase one deals with the establishment of the operation;

(2) Phase two involves the longer main operational stage; and

(3) Phase three entails the termination of operations and final rehabilitation of the property.

The vertical axis or "Disturbed Land/Rehabilitated Land" factor involves two elements:

(1) the operational area, which includes the processing and supporting functions; and

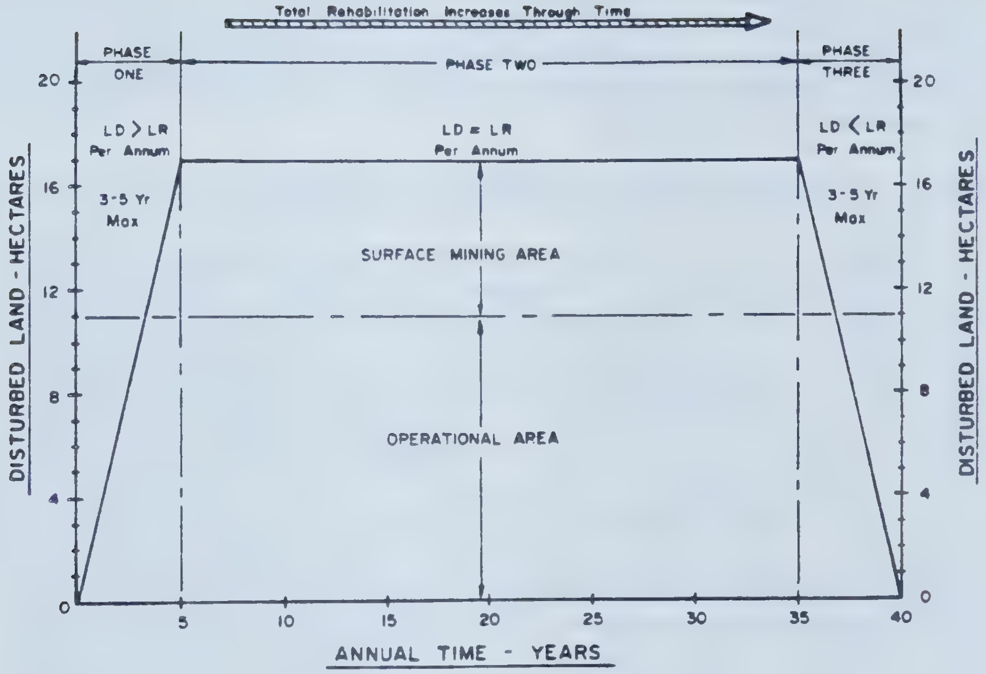


Figure 3. Rehabilitation time model.

(2) the surface mining area, which includes the areas in process of excavation and rehabilitation (approximately the C&B in Figure 1).

Factors contributing to the operation magnitude are:

(1) total hectarage to be mined;

(2) plant capacity and annual production; and

(3) thickness of resource being extracted.

We have used a common, albeit, large operation set of data in our example (see Figure 3) viz 80 hectares, 450,000 tonnes per year and 12.5 metres resource thickness. Other operation characteristics would change the dimensions and appearance of the model but not the concepts.

Some Factors Involved in Operationalizing the Model

The first phase of the "Rehabilitation Time/Performance Model" takes 3 to 5 years to mature. During this phase the processing plant, buildings, siltation ponds and surface mining operation are established. At this time due to the "static" disturbed hectares, (plant, equipment, storage sheds, siltation ponds, etc) areas stripped of overburden, under excavation and under rehabilitation, the area of land disturbed is greater than the area fully rehabilitated. The amount of land disturbed in relation to the surface mining area can vary throughout the life of the operation, but the "static" disturbed hectarage should become fairly stable. Rehabilitation procedures do not start on a property until the second or third year, as the first overburden material is utilized in screening berms on the perimeter of the property. It is clearly of primary significance to operator and government inspector alike to determine the annual rate of rehabilitation and maintain a minimal disturbed land hectarage during the long second phase of the "Rehabilitation Time/Performance Model."

The third phase of the "Rehabilitation Time Model" is the final one. A relatively large percentage of rehabilitation is completed during this phase. As the aggregate reserve dwindles, mining and processing winds down, land covered by stockpiles, loading areas, and silt pond areas are rehabilitated, disturbed land hectarage very rapidly dwindles. Land rehabilitated per year throughout this short period (3 to 5 years) exceeds the amount disturbed. This "Model" will provide guidance for licenced operators to determine the amount of land that should be disturbed or rehabilitated at any given time in the life of their operation. The model will serve the same useful purposes for the Ontario Government to set performance standards and assist in the administration of and ability to measure the success of their new Aggregates Act.

Other Necessary Input to Operationalize the Model

In a 1982 survey of more than 100 aggregate operations performed using air photographs and site plant examination, the following facts seem to represent disturbed land value norms which may be considered as relatively "static" or fixed in location during an operation:

(1) Processing plant and stockpiles - 4.5 hectares

(2) Settling ponds - 4.0 hectares

(3) Office and weight scales - 0.5 hectares

(4) Maintenance and scrap area - 1.0 hectares

(5) Parking area - 1.0 hectare

Total "Static" Disturbed Land Area = 11.0 hectares

In addition, our "average operation" as envisaged in Figure 3, the Time Rehabilitation Model would have a constantly changing (in location):

(6) Area stripped of overburden - 2.0 hectares

(7) Excavation area - 2.0 hectares

(8) Area under rehabilitation - 2.0 hectares which together with the "Static" Disturbed Land - (11 hectares) = Total Disturbed Land Area = 17.0 hectares

This data can be revised in an important alternative way (Figure 4). Using the 100 plus pit sample it as seen that the line on the right represented the greatest disturbed acreage for any particular tonnage output.

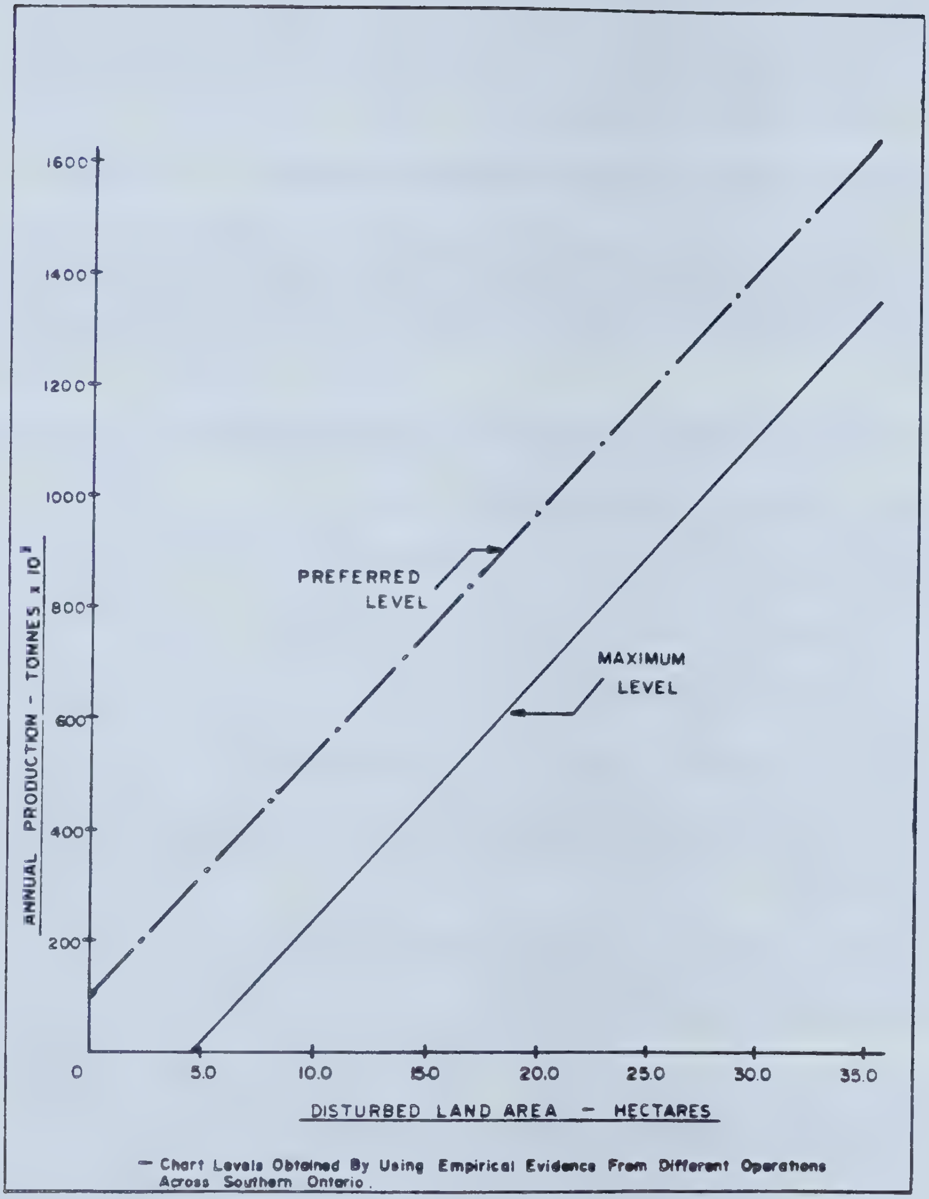


Figure 4. Chart for determination of disturbed land area.

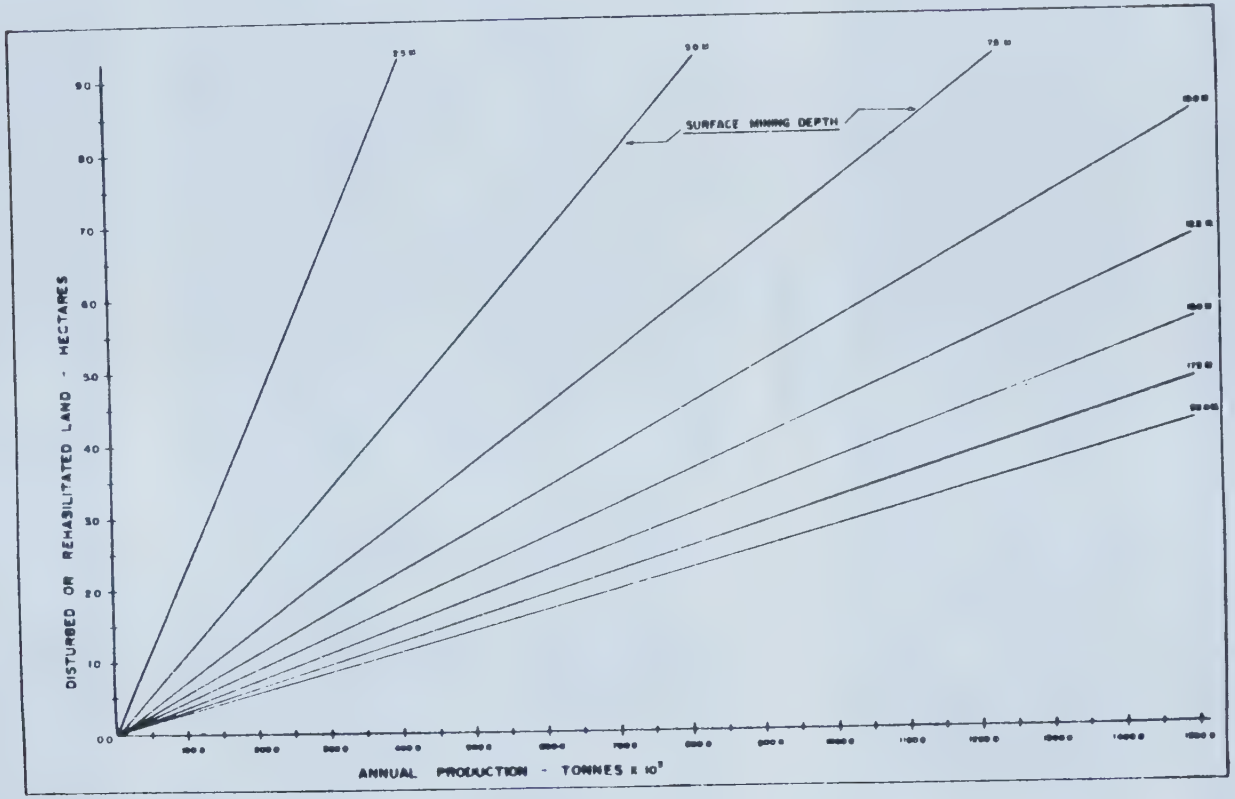


Figure 5. Rehabilitation model - Phase 2. Disturbed/rehabilitated versus annual production.

In other words even under today's imperfect standards all operators can easily position themselves between the two sloping lines . . . under improved progressive rehabilitation standards all should be to the left of the "preferred" standards line and inspectors can use this as a guideline.

Clearly the exact position of the preferred line on Figure 4 should be a function of what is reasonable and government policy. Since the data presented here are based on actual observation it is suggested that the demands in Figure 4 are in no way excessive.

Need for Flexibility

Flexibility should be allowed for legitimate site problems. For example substantial tonnage increases due to the acquisition of major contracts might, at least temporarily increase disturbed areas used for stockpiling, processing, transportation, etc. Similarly, considerable fluctuations in deposit thickness and quality variations may result in temporary difficulties in meeting rehabilitation quotas demanded in Figures 3 and 4. Figure 5 presents an opportunity to calculate how disturbed acreage should fluctuate due to resource thickness and annual production. Clearly very thick deposits yield greater tonnages per disturbed hectare and conversely thinner geological strata involve greater land disturbance for similar production. An empirical graph such as this based on Southern Ontario evidence should be used as input into the "Rehabilitation Time/Performance Model."

CONCLUSION

It has too often been said and too often been true that giving a licence to mine 200 hectares has meant the withdrawal and sterilization of the 200 hectares of agricultural land during the complete lifetime of the pit/quarry. The objective of government regulatory control has been to limit this unwarranted interference and to ensure a rapid transition back to healthy agricultural activity. The major problem has been in monitoring the performance and ensuring satisfactory rehabilitation progress.

The implementation models presented here for the first time, suggest a fair, but constraining system to gauge aerial disturbance and aerial rehabilitation. It is suggested that the average operation of an 80 hectare licence would not normally result in the disturbance of more than 15 to 20 hectares at any point in time, ie, less than one-quarter of the whole property. Increasing the size of the operation and the production would not result in a similar increase in disturbed area. The largest Ontario operation with which the authors are familiar occupies a 600 hectare licence and produces a maximum of 5 million tons from a deposit 20 meters thick. In this case the preferred disturbed acreage would amount to approximately 50 to 80 hectares, but no more.

With operational/rehabilitation procedures like these in place, many of the conflicts around aggregate mining will be more perceived than real, a common set of goals can be agreed on by government and the producer, and some of the anti-government and anti-industry fears of the public may in fact be demonstrated to be groundless. Aggregate mining and agriculture and other land use activities could be common and compatible activities on the same property.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of the Ontario Government - Ministry of Natural Resources in allowing access to some of the empirical data in this article.

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INTEGRATING ENVIRONMENTAL AND LANDOWNER CONSIDERATIONS IN THE RESTORATION OF PIPELINE RIGHTS-OF-WAY

Hare, M. O., and W. H. Watt, TransCanada PipeLines Limited

ABSTRACT

During 1982 TransCanada Pipelines constructed a 425 km, 914 mm diameter natural gas pipeline in new right-of-way from North Bay to Morrisburg, Ontario. The construction of the pipeline and subsequent restoration of the land to its former were accomplished after nearly 2 years of planning (including project feasibility and route selection), environmental assessment, and engineering design work. Liaison with local agricultural organizations, municipalities, provincial and federal agencies and individual landowners was continuous throughout the planning and construction phases. This paper will focus on the integration of environmental and landowner concerns into the planning, construction and land restoration processes of the North Bay Shortcut pipeline project.

INTRODUCTION

The "North Bay Shortcut" is a 425 km, large-diameter (914 mm) natural gas pipeline extending from TransCanada's existing compressor station at North Bay, Ontario, to the junction of its Ottawa Lateral and Toronto - Montreal Lines, near Morrisburg, Ontario. In this way it is a shortcut, by-passing the built-up and urbanizing areas of central Ontario, and permitting more economical gas transmission. Construction commenced in January 1982 and was completed in December of the same year. Final clean-up was completed in August 1983. The pipeline was constructed entirely in new right-of-way, which was negotiated with 584 private landowners and 17 government agencies, without a single expropriation.

The National Energy Board (NEB) hearing, required by law to determine whether the pipeline is in the best public interest, lasted only eight days. Furthermore, the construction proceeded on schedule and within budget, while at the same time implementing sound environmental practices and mitigative measures. The restoration results have been very encouraging to date.

This paper describes the key elements of the approach adopted to integrate landowner and environmental considerations into the North Bay Shortcut project, with emphasis on planning, practice, and results.

PLANNING

Five major steps taken in integrating environmental and landowner concerns into the project planning process will be outlined in this section. These are discussed neither chronologically (as they were undertaken concurrently) nor in any order of importance.

Multi-Disciplinary Approach

Throughout the duration of this project, a multi-disciplinary team approach was used. This is hardly a new idea, but it is one more often advocated than effectively carried out. Throughout the route selection, environmental assessment and pipeline design phases and during the preparation of detailed recommendations and construction plans, a conscientious effort was made to involve pipeline design engineers, construction experts, right-of-way agents and environmental analysts in the decision making. In this way, there was a common consensus and commitment to the objectives of the project, including those of environmental and landowner protection.

Landowner Meetings

Regional meetings were a very effective means of involving farm landowners in the project and of identifying their concerns. These meetings were organized through the Ontario Federation of Agriculture (OFA), and were looked upon by TransCanada as information exchanges, not simply as presentations to the public. They were seen as opportunities to obtain site-specific information, and to identify and discuss the key concerns of landowners affected by our proposals. Not only was information gathered which convinced TransCanada to alter the proposed pipeline route in certain areas, but landowner reaction made it apparent that additional consideration would have to be given to some specific concerns, such as tile drainage repair. In this case, it was determined necessary to have special drainage inspectors present during construction, in addition to the on-site environmental inspectors.

One reason for the success of the meetings was that key TransCanada people, responsible for various aspects of the job, were present. This included, in most cases, the Managers of our

Right-of-Way and Environmental Affairs Department and the Pipeline Design Project Leader. This reinforced TransCanada's commitment to take the concerns of the local people seriously. The consultant who had prepared the environmental assessment report was also present at the meetings in an advisory role. However, the meetings themselves were chaired by OFA representatives and were held in community centres along the route - Stittsville, Pembroke, Winchester.

Having an interest group act in a co-ordinating role for the public meetings was new for TransCanada and we believe that it improved the effectiveness of the community input, creating an informal and co-operative atmosphere and contributing to a free exchange of ideas.

Landowner's Brochure

The third element of the approach was to ensure that all parties affected by the proposed line were aware of the project. A landowner's brochure (TransCanada PipeLines Limited, 1982) was therefore prepared and distributed to everyone affected by the proposed pipeline. The brochure described both TransCanada and the project under consideration - the route selection process, the proposed construction procedures and how the land would be restored. In addition, the brochure contained telephone numbers for contact persons at TransCanada able to provide further information.

Provincial Contacts

District, regional and head office staffs of provincial government departments were contacted in order to identify environmentally sensitive areas and issues. These included the Ministries of Environment (MOE), Natural Resources (MNR), Agriculture and Food (MAF), Culture and Recreation (MCR) and certain Conservation Authorities. These contacts were made at several times throughout the study. The first contacts were made during the route selection phase, when government agencies were consulted to help generate constraint mapping information and to advise about the sensitivity of stream crossings, wildlife areas, forestry management areas, special agricultural uses, etc. This information was used in preparing the environmental assessment report. These agencies were contacted again once a route had been selected, and a two day meeting and field trip was held to review the route with government representatives. When the environmental assessment was filed with the NEB, copies were also provided to these local government offices through the Ontario

Pipeline Coordination Committee (OPCC). And finally, after receipt of NEB approval to construct the pipeline but prior to the actual start of construction, meetings were held with district MNR, MOE and MAF staffs to explain the construction schedule and procedures and to discuss any final environmental concerns.

Municipal Contacts

As the fifth major way that environmental and landowner concerns were integrated into our planning process, every municipality and township affected by the pipeline was contacted prior to construction both at the staff level, and at the elected representative level. The project was explained, concerns noted,

and in some cases minor modifications made to the route to accommodate the future development plans of the township or municipality.

These five elements of the approach taken during the planning of the North Bay Shortcut project greatly contributed to public acceptance of the pipeline by ensuring that landowner and government concerns were first identified and then addressed with appropriate mitigative measures or restoration techniques. This does not mean that there was no opposition to this project at the public hearing or that there were no environmental problems or challenges during construction. However, the fact that a pipeline of this magnitude was negotiated with every landowner, and built on time and within budget is reason to believe the approach was successful.

PRACTICE

Construction of the North Bay Shortcut caused the temporary disturbance of approximately 13 km^2 of land. Individual properties remained in a disturbed condition for between six months and one-and-one-half years. With heavy equipment and various contractors moving across their land for that period of time, many landowners were justifiably concerned about the possible impacts of construction. The Pipeline Construction Specifications (TransCanada PipeLines Limited, 1981) describe general practices for protection of farmlands and the environment, and a detailed environmental assessment (Duncan, 1980) provided site-specific recommendations which were incorporated into the construction contracts. However, a number of other practices and procedures were followed during construction to help ensure that landowner concerns were properly addressed. The remainder of this paper describes the steps taken by construction supervisors (responsible for the administration of construction contracts and for supervision of the work), right-of-way agents (responsible for all communication with landowners), and consulting environmental inspectors (provided technical support and an independent audit of environmental practices) to integrate landowner wishes into the construction and clean-up phase of the project.

Pre-construction Report

Prior to construction, a right-of-way agent visited each landowner to discuss the project with him, and to determine whether there were any specific concerns or requirements on his property. Information regarding such matters as access, timber salvage, topsoil handling and temporary fencing was entered on Pre-construction Reports, which formed part of the construction contract, and were thus binding on the Company and its contractors. These Pre-construction Reports were also filed with the National Energy Board whose field representatives audited compliance. During construction right-of-way agents, company inspectors and environmental inspectors worked together with landowners to ensure that these requirements and other reasonable requests were accommodated wherever possible.

Tile Drainage

During the planning phase, tile drainage was recognized as the most important landowner concern on agricultural land. Efforts were therefore made to avoid systematic tile wherever feasible. Because this was not always possible, local tile drainage experts were retained to meet with landowners and obtain existing drainage plans. Where no plans existed, they walked each field with its owner to locate and record existing tiles. Some 84 existing systems were verified by these means.

They then prepared new plans indicating how best to repair or modify the drainage system to function in the presence of the pipeline. In addition, there were 30 properties where tile was not yet present but planned for the future. Here the drainage experts surveyed the fields and determined whether extra depth of cover would be necessary over the pipe to accommodate future crossovers, collector drains or outlets.

During construction, these same drainage experts, now serving as representatives of the Ontario Federation of Agriculture inspected the cutting, interim maintenance, and final repair or modification of each and every drainage system, ensuring that it met the highest standards, and that it satisfied the original landowner agreement.

In all, 300 subsurface drains were permanently repaired. A total of 58 drains were temporarily repaired in the fall of 1982, so that drainage would function properly the following spring. In 1983, 14 of these temporary repairs were made permanent, while on 43 properties, system modifications effectively replaced 147 drain crossings.

Topsoil Stripping

Topsoil stripping was another issue on which landowner input was sought. Each farm landowner was given the option of having topsoil stripped from the trench-line only, from the trench-line and spoil stockpile area, or from across the full width of the working right-of-way. There are advantages and disadvantages to each practice and these must always be weighed on a site-specific basis. Where a landowner was uncertain or requested further advice, a knowledgeable environmental inspector reviewed with him the construction process, the potential impacts, and the various restoration measures available. In a large majority of cases, the landowner chose to have the trench and spoil areas stripped, though each of the other options was also selected. TransCanada continues to monitor the effects of topsoil stripping and replacement so that the relative benefits will be better defined for landowners in future, and the choices made correspondingly easier.

Subsoiling to Mitigate Compaction

During construction, compaction of subsoil to depths of 45 or 50 cm along the travelled working side of the right-of-way was recognized as a serious concern, and it was noted that the chisel cultivators normally used to loosen the soil were not achieving sufficient depth. Initially, a grader equipped with ripper teeth was employed to loosen compaction. This worked fairly well on dry coarse-textured soils, but proved inappropriate for use on soils with higher clay or moisture contents. Prior to clean-up in 1983, a team of soil scientists examined all agricultural fields on Spread 3 using penetrometer and bulk density measurements to assess the depth, degree and extent of compaction, and to formulate recommendations for its mitigation. By this time, the contractor had provided a specially designed, commercially available agricultural subsoiler. However, there remained a number of obstacles to its use: first, the possible lifting of stoney overburden into normal plough depth; second, the possible interference with shallow tile drains; and third, the possible mixing of topsoil and subsoil. Wherever these conflicts were a possibility, the right-of-way agent contacted the landowner to advise him of the subsoiling recommendations, giving him the option of rejecting subsoiling in favour of conventional chisel ploughing and cultivation. Where a landowner was uncertain or requested advice, the soils consultant or the environmental inspector would meet with the owner to discuss the alternative practices.

In all, 85 properties were systematically probed with penetrometers and/or sampled for bulk density at two or three depths on and off the right-of-way. Of these, 77 were subsoiled, mostly to a depth of 45 cm, except where patches of stony till were encountered. The totallength of the right-of-way subsoiled was approximately 42 km.

Fertilizer Application and Seeding

The environmental assessment and hence the construction contract, provided for the application of phosphate fertilizer to the subsoil prior to respreading of topsoil, this being intended to promote root growth and help knit the soil profile back together. Fertilizer application to topsoil was given as a general recommendation which could be adjusted up or down at landowner request and/or upon soil chemical analysis to suit the landowner's cropping practices. Environmental inspectors assisted in verifying such requests on a site-specific basis.

Landowners were given the choice of three standard seed mixes, or a modified mix of their preference. The standard mixes were specially designed for forest clearings and roughlands, for low maintenance pasture and roadsides, or for improved pasture. Some owners requested no seeding, where corn or grain was to be sown next spring, or where they preferred to handle it themselves. One standard seed mix was modified for use near North Bay, when the environmental inspector learned that local farmers considered one of its components undesirable.

Crown Land

A substantial amount of Crown Land was crossed on Spreads 1 and 2. Here any special concerns or requirements were contained in work permits issued by MNR District Offices. During construction, each District appointed a representative - in one case a full-time field inspector - who worked with Company construction personnel, right-of-way agents and environmental inspectors to help ensure that requirements were met. MNR landscape architects designed planting plans in areas such as the Mattawa River Provincial Park, and provided some of the nursery stock. The Company then included the landscape plantings in its clean-up and restoration efforts.

Watercourse Crossings

In the case of watercourse crossings, several owning authorities were usually involved. Provincial concerns were collected by the OPCC and conveyed to the NEB, whose representatives monitored compliance with crossing plans.

MNR and MOE also provided contact persons and field representatives. In most cases, crossings proceeded according to original design, but in a few cases conditions required changes in procedure. Where changes were necessary, consultation among construction supervisors, environmental inspectors and regulatory representatives helped to determine the most suitable crossing techniques and restoration measures. Streams were restored as soon as possible after installation of the pipe. Where construction continued into the late fall, stream banks and valley slopes were provided with interim erosion control.

Review of Landowner Requests

The environmental inspector provided technical support to the right-of-way agent and landowner in a number of ways during where construction. The spoil displaced by the pipe and the extensive grading necessary to establish access, for example, made the hauling away of extraneous fill a major item on the North Bay Shortcut. Fill or dump sites were necessary at frequent intervals - and, as usual, these were not very difficult to find, since many owners seemed to have a low spot that needed filling. Before material could be disposed of in a fill site, however, the right-of-way agent had the environmental inspector verify that the site did not conflict with fill or flood plain regulations, that it would not result in impeded drainage, and that it did not encroach upon significant wetlands or waterbodies. Conservation Authorities having jurisdiction were consulted when appropriate.

Similarly, the environmental inspector checked that any stream diversions or permanent culverts requested on the right-of-way by landowners were in compliance with provisions of the Lakes and Rivers Improvement Act, R.S.O. 1980, c.229. MNR was occasionally called in to help determine whether permit applications were necessary.

Occasionally, the right-of-way agent called upon the environmental inspector and his records of construction to help resolve a contentious issue, and to help ensure that a fair resolution of the matter was reached. Water well records, timber evaluations, topsoil depth, soil fertility, and even an incidence of blackleg in a nearby herd of cattle required investigation by the environmental inspector. In a small number of cases more specialized expertise (e.g., of hydrogeologists, veterinarians, chemical engineers, or wildlife biologists of Ducks Unlimited) had to be called in to settle a complaint, and NEB representatives participated in on-site meetings with landowners when so requested.

RESULTS

The strength of a system like this is its flexibility - dealing with each concern as it arises permits unique solutions to unique problems. The difficulty of such a system is that it calls for a great deal of communication among a great number of people with widely varied skills.

The North Bay Shortcut thus owes its success to the cooperative efforts of engineers, right-of-way agents, construction supervisors and inspectors, contractors, environmental experts, regulatory bodies, and especially landowners.

The degree of success achieved is described in a series of post construction environmental reports prepared by TransCanada and its environmental consultants. (TransCanada PipeLines Limited, 1983 a, b).

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LAND RECLAMATION AND URBAN DESIGN
- AN ECOLOGICAL VIEW

Michael Hough
Hough, Stansbury Michalski Limited
Toronto, Ontario

ABSTRACT

This paper addresses an arcane and little recognized set of issues that have to do with human perceptions toward the urban environment and the need for land reclamation in cities. The propensity to think of the grass as being greener on the other side of the fence, leads inevitably to a search by designers for solutions to environmental issues that ignore their own doorstep. Landscape architecture now recognizes ecology as the basis for planning and design, but ignores ecology in the design of cities. The expansion of industrial cities over the last 100 years, the dominance of technology in human life and culturally determined aesthetic values have created two landscapes in the city. The first is a cultivated landscape of parks whose exclusive focus is amenity and recreation. The other is a vernacular landscape created from natural and cultural processes that have no place in the established vocabulary of urban design. The latter is regarded as derelict, in need of rehabilitation, but is, in fact, often ecologically diverse. The former is seen as the desirable rehabilitated landscape, but is often, in fact, ecologically sterile. This paper examines the conflicts of environmental values inherent in the city and illustrates by way of case studies how a new urban design form can arise when an ecological and conserver view of the city becomes central to the design process.

This paper deals with the urban environment - the legacy of unbuilt-on land that has been incorporated into the city as it has expanded - the parks and open spaces, the vacant, marginal or derelict lands. Since environmental perceptions and policies are largely urban based, and since the city is the most severely modified of all natural environments, it makes sense to consider the question of land reclamation in the context of urban design. Indeed, it must be of prime concern because we are dealing with the health of the places most of us live in.

The term derelict land is commonly used to mean land that has been damaged by some use or process and then neglected. In a landscape sense, its interpretation involves the abandonment of care for its appearance - giving offense to the eye (Oxenham, 1966). It is here that we run into problems, however. In my view, the emphasis placed on aesthetic judgements in both reclamation and design matters requires re-evaluation. In the absence of underlying social or ecological contexts, aesthetics become suspect as the basis for making decisions about land. Over the last 10 to 15 years it has been generally recognized that biophysical processes cannot be ignored in questions of land planning and must be regarded as a central factor in decisions affecting the larger landscape. Yet urban design operates largely on the premise that ecology is either nonexistent in cities, or has little relevance to urban issues.

If we look at the city from an ecological perspective, we find two general categories of landscape existing side by side. One is a nurtured landscape of parks, gardens, well maintained housing developments and industrial estates; flowerbeds, turf, shrubs, and specimen trees. This is a landscape reflecting prevailing values of civic pride and care. It owes its form and survival to established conventions of design aesthetics handed down to us from the last century, and to horticultural science and technology. The mown turf and specimen trees of the housing estate and park are the city's monocultures - the international ground and tree cover that has very little to do with its site, soils, microclimate and other environmental variables that make one place different from another. This cultivated landscape is the urban expression of land reclamation and is based on prevailing aesthetic values.

The other exists behind this facade. It is a landscape of abandoned industrial property and waterfronts, vacant lots, disused railway lines and canals that lie outside the parks system. These are seen as unproductive, neglected, lacking in social usefulness. Yet if we examine much of this landscape, we find that it consists of complex naturalized woodlands and marshes and old field communities that belie the label "derelict." A comparison between the plants and animals present in a regenerating vacant lot and those present in a landscaped front yard or city park, reveals that the vacant lot generally has far greater floral and faunal diversity than the city park or front lawn. Yet all efforts are directed toward nurturing the latter and suppressing the former.

These two landscapes reflect inherent contradictions and values in the way we view the environment. If we make the not unreasonable assumptions, first; that land reclamation involves the restoration of land from a degraded state to a state of fertility and health to enable it to perform useful environmental and social functions; second, that diversity is ecologically and socially necessary to the quality of urban life, then we have to challenge current assumptions and values. The preoccupation with horticulture and formalized aesthetics dictates an approach to rehabilitation that is both inappropriate and increasingly costly in the future management of urban land. Current practice, in fact, is geared to reducing diversity and choice rather than enhancing them. In so doing, it creates, by conscious endeavour, the very derelict conditions it is intent on curing. A few examples will illustrate the point.

1. The Outer Harbour Headland on the Toronto waterfront is a spit of land two and a half miles long, built some 20 years ago to create a new harbour in expectation of greatly increased shipping tonnage. This additional shipping never materialized, however, and since that time the future of the headland has remained in limbo. Environmentally though, the headland represents a fascinating example of the power of natural process. From the loose rubble and subsoil from which it was built, a new landscape has begun to evolve. Wind and wave are grinding bricks and concrete to sand; marshland and mudflats have appeared that now provide habitat for thousands of breeding and migratory gulls, terns and waders. Among them is the rare Caspian Tern, whose breeding sites are becoming increasingly scarce on the Great Lakes. The headland, in fact, has now become a bird sanctuary of major significance on the Great Lakes System as other habitats have been eliminated. A forest of cottonwood, willow, and aspen is developing and has grown to over 5 metres in height. Some 150 species of plants have migrated here and established themselves (McNab, 1978). Some, such as the Sticky Groundsel, are found nowhere else in the Toronto Region (McNab, 1978). Within the open space resources of the waterfront, the headland now represents a unique resource for education, scientific study, and passive recreation. Yet there are overwhelming pressures to reclaim this "derelict" site, to transform it to a formal landscape of boat slips, parking lots, picnic sites, turf, and cultivated plants. Elsewhere on the waterfront, one can see the consequences of this urge to landscape to an appropriate function and

aesthetic, which has created places of complete banality and tedium. The only thing saving the Leslie Street Spit from the sterilizing influence of established development is a poor economic climate that has, up to now, made such a project too expensive.

2. The reclamation of mined out lands in Britain's famous Black Country has often replaced a naturally regenerated landscape of great diversity and educational use, for green deserts of grass and specimen trees.

3. Traditional storm drainage systems, the conventional way of keeping one's shoes dry in town, have until recently, been unquestioned. As the established vocabulary of engineering, water drains to the catchbasin. But the benefits of well drained streets and civic places is payed for by environmental costs downstream in eroded banks and impaired water quality and the creation of new derelict landscapes. Many an abandoned industrial site where water has been impounded by accident has become rich and beautiful wildlife habitat and entirely self-supporting. Rehabilitation inevitably leads to ecological and consequently visual impoverishment.

The question that arises, therefore, is this; which are the derelict sites in the city requiring rehabilitation? Those fortuitous and ecologically diverse places representing urban natural processes at work, or the formalized landscapes imposed by urban man? It is my contention that the formal city landscape imposed over an original natural diversity is the one in need of rehabilitation. While it will be obvious that horticulture has a place in the city, my point is that its universal application as the basis for urban form is the most persuasive argument for considering the city as a derelict landscape.

What are the alternative approaches we can take?

Our primary concern is how we can make cities environmentally and socially healthier. In my view, we must replace worn out aesthetic conventions with an approach to urban land management and rehabilitation that is based on an ecological view. Aesthetics, as I have said, have validity only when placed in context with underlying biophysical determinants. This way is inherently more diverse, more socially relevant. It is also a great deal more economical, a fact that cannot be ignored when maintenance and upkeep costs are forcing parks departments and other agencies to seek new ways of managing land.

1. At the large scale of urban land planning, the regenerating areas of the city that have special value as habitat should be recognized and integrated into the open space network and development. This would include such places as remnant natural areas, disused railway lines and waterfronts, etc. It would provide a city-wide variety of choices and places - some manicured an highly used, some wilder and catering to passive and educational uses and conservation.

2. Land barred from the public, for reasons of security or ownership, often regarded as derelict, may also be rich in flora and fauna and provides evidence that nature is often the most appropriate agent of rehabilitation. By making use of such opportunities, rich and varied open space patterns may be developed on lands not normally conceived as having recreation or environmental value. The Gulf Oil refinery in Mississauga, Ontario is one example of this principle. The refinery, surrounded on three sides by residential communities, decided, some years ago, to improve relations with its neighbours by providing a landscaped buffer between the residential areas and refinery operations. This decision led to the establishment of a wildlife area within refinery boundaries. A series of habitats were created including an open body of water, a small wetland, woodland, and linear forest planting to provide a link with the Rattray Marsh and Lake Ontario. Since access to the new wildlife area is prohibited for reasons of security, observation points outside its boundaries were built into the plan for people in the community to see wildlife. In addition, the area is totally self-sustaining, requiring no maintenance. So the productive use of otherwise unproductive land and environmental and social benefits were brought together.

3. Conventional planting based on climax species planted according to horticultural procedures tend to create static design solutions and do nothing to rehabilitate sterile soils. Maintenance procedures provide no basis for continuing

and evolving plant associations for the future. The experience of the dutch landscapes based on natural succession management techniques, offers a creative alternative that is in tune with social need and provides long-term low maintenance landscapes. The now famous Delft experiment has demonstrated how the concept of urban forestry enhances social and environmental benefits. Wooded landscapes maintain more equitable climate through the absorption of solar radiation, evapotranspiration and reduction of winds and pollution. Socially, they provide self-sustaining low cost landscapes and diverse environments of open and enclosed spaces. There are immediate and long-term benefits in forest cover, diversity of wildlife, hardy and creative children's play, and enhanced amenity.

4. The maintenance of grassland by the mowing machine has gone far to create the ecological deserts that come under the label of landscaping. Economic forces and to some extent, old tradition, are pointing the way to less costly and more beneficial alternatives to the management of these immense acreages of international groundcover. In Britain and Europe we find urban common lands, churchyards, and playing fields kept mown by livestock through agreements with farmers. An industrial oil storage site in the Borough of North York, Toronto has maintained the turfed berms surrounding storage tanks with sheep for 12 years. The engineer who originated the idea found that his costs in equipment, fuel and manpower were practically eliminated. The more intelligent use of the lawnmower would also create a more diverse habitat and reduce costs along roads and other areas that need to remain open grassland.

5. The multifunctional design and management of urban land based on ecological and social determinants can provide the foundation for the design alternatives that we seek in this enquiry. Its application is admirably demonstrated in the Zurich forest park system. Although this example is the consequence of a unique set of social and political circumstances, it provides us with some relevant principles. The Zurich forest parks of some 2 600 hectares surrounding and penetrating the city have for generations been managed for forestry products, wildlife, recreational uses and amenity. Logging is carried out in winter and employs sophisticated silvicultural techniques and reforestation practices. Roads

and path systems are designed to accommodate exercise trails, walking and resting places, and interpretive programs describing the plants and geology of the region. In addition, the parks system includes agricultural land that is leased to local farmers for small scale crop and livestock production. Maybe the most impressive aspect of this parks system is the fact that recreational facilities are paid for by the production of the forest lands (by up to 50 percent in 1980). We find here an example of integrated resource management within a city that is both profitable and socially useful and where exploitation and rehabilitation is the basis for land management.

I should like to sum up briefly a few final comments.

1. We will have to re-examine the conventional framework on which the design and management of urban land has traditionally been based. The concept of land reclamation as it applies to cities will require an ecological view. This will become increasingly necessary as we search for more economical and practical ways of maintaining our parks and open spaces and as a means of enhancing the variety of choice and quality of urban life.

2. We should be working toward incorporating the total open space resources of the city into planning as well as the parks, since they are essential to its environmental and social richness and diversity.

3. Open space systems in the future will likely be required to serve multiple functions besides recreation which has traditionally been the role of parks. These might include climate control, water conservation, wood production, and urban food growing.

Since our views on land rehabilitation are largely urban in origin, it seems to me that an intelligent approach to conserving and enriching the urban landscape is a step in the direction we should be taking toward the environment as a whole.

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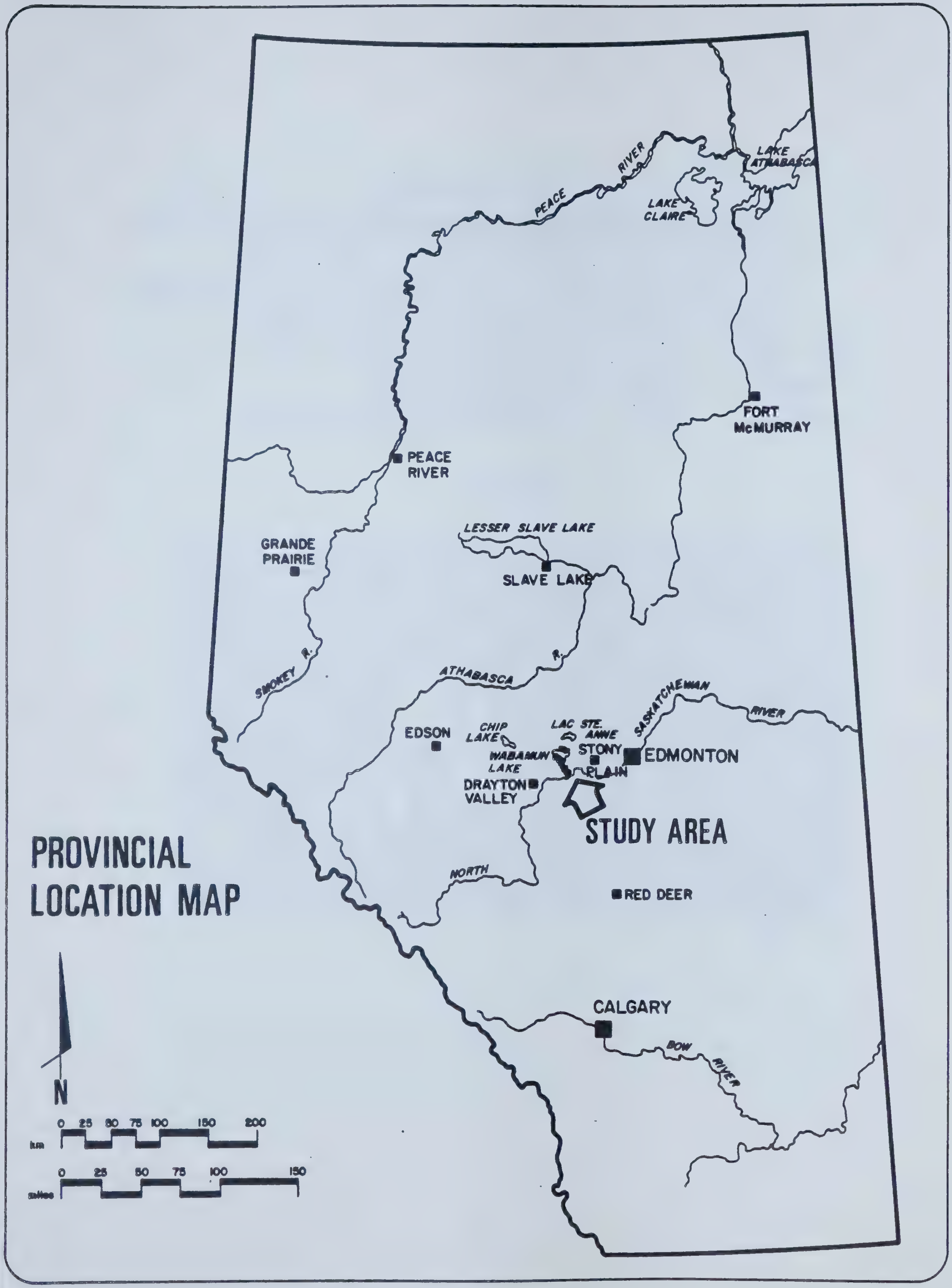
WHITEWOOD FUTURE LAND USE STUDY

J.K. STEWART	MCIP	Epec Consulting Western Limited
M.D. EVANS	CSLA	Earthscape Consultants
M. BOEHM	P.Ag.	Monenco Consultants
H. QUAN	B.Sc.	TransAlta Utilities Corporation

ABSTRACT

In order to satisfy government and planning needs, TransAlta Utilities Corporation and the County of Parkland No. 31 jointly funded a project to produce a long-range land use plan for the area encompassed by the permit boundaries for the Whitewood coal strip mine. Inventories were conducted to map natural parameters such as soil and vegetation; this information was digitized and synthesized by computer to map capability and suitability for 107 possible land uses. These land uses were then categorized on the basis of similarity and seven representative land uses were chosen; this entire procedure was conducted for a "pre-mine" scenario, which assumed that mining had never occurred and afforded a basis for estimating the impact of mining upon land capability for a "post-mine" scenario, based upon drill hole data and mining methods. The resulting map was digitized and assessed by computer for capability and suitability for the same representative land uses as described above. In both cases, economic trends were applied to the land use plans, and a final long-range land use plan was developed.



PROVINCIAL LOCATION MAP

PEACE RIVER
LAKE ATHABASCA
LAKE CLAIRE
FORT McMURRAY
PEACE RIVER
LESSER SLAVE LAKE
GRANDE PRAIRIE
SLAVE LAKE
SMOKEY R.
ATHABASCA R.
SASKATCHEWAN RIVER
EDSON
CHIP LAKE
LAC STE. ANNE
STONY PLAIN
EDMONTON
WABAMUN LAKE
DRAYTON VALLEY
STUDY AREA
NORTH
RED DEER
CALGARY
BOW RIVER
N
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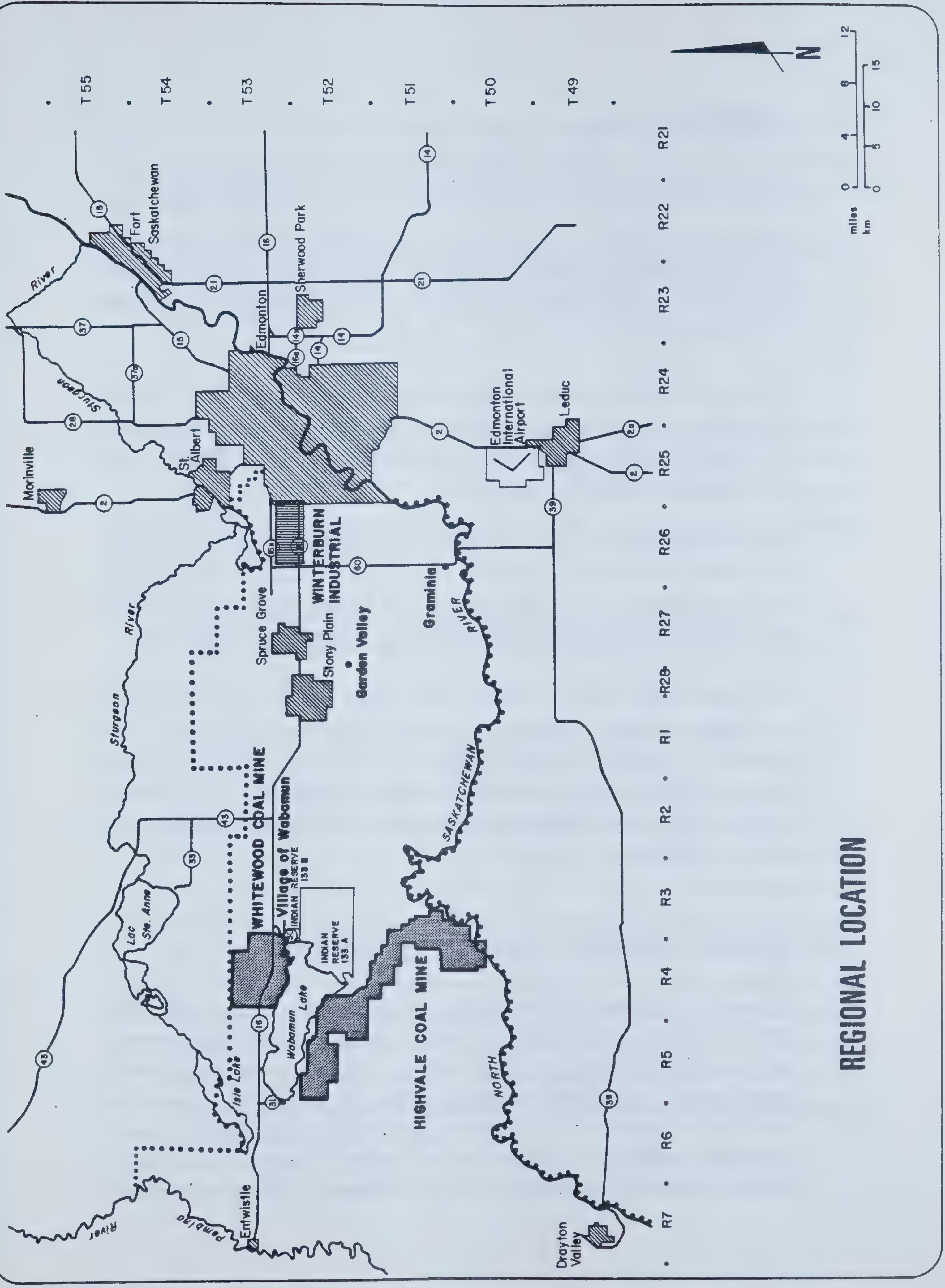
km
0 25 50 75 100 150
miles



REGIONAL LOCATION

T 55
T 54
T 53
T 52
T 51
T 50
T 49
R7
R6
R5
R4
R3
R2
R1
R28
R27
R26
R25
R24
R23
R22
R21
N
miles
km
0
4
8
12
0
5
10
15
Morinville
St. Albert
Edmonton
Sherwood Park
Fort Saskatchewan
Edmonton International Airport
Leduc
Spruce Grove
Stony Plain
Garden Valley
WINTERBURN INDUSTRIAL
Graminia
WHITEWOOD COAL MINE
Village of Wabamun
INDIAN RESERVE 133 B
INDIAN RESERVE 133 A
Wabamun Lake
HIGHVALE COAL MINE
Lac Ste. Anne
Isle Lake
Entwistle
Pembina River
Drayton Valley
Sturgeon River
NORTH SASKATCHEWAN RIVER
River
43
28
37
37a
15
21
16
16a
14
14x
2
2a
39
60
16x
33
31

1.0 INTRODUCTION

Land use planning and reclamation planning of drastically disturbed lands have, in past years, been separate activities. Often land uses after mining are identified by public decision makers or senior government administrations in very general terms or on the basis of the replacement of land uses which existed before mining activities began.

Reclamation planning and practice have become increasingly sophisticated in past years. In spite of the sophistication in techniques, reclamation planning is often targeted towards general land use categories such as "agriculture" or "wildlands".

The Whitewood Future Land Use Study (presently in its final stages of report production) represents an attempt to connect the land use planning exercise with reclamation in a manner which would realize some of the opportunities represented by disturbance of the land.

The method and results of this study appear clearly appropriate to the theme of this, the 8th CLRA meeting - "Planning, Practice, and Results". We wish in this paper to describe our methods and our results briefly, and thereafter develop a dialogue with participants at this forum concerning the positive and negative aspects of such an approach.

2.0 THE NEED TO RATIONALIZE JURISDICTIONAL DIFFERENCES

TransAlta Utilities Corporation is Alberta's largest electric utility, with a generating capacity of some 3355 MW of power. Although some of this power is derived from the operation of small hydro plants, by far the greatest portion of TransAlta's generating capacity - about 85% - is from the burning of thermal coal. TransAlta owns and operates two of Canada's largest coal strip mines, 60km west of Edmonton at Lake Wabamun. Of these two projects, it is the Whitewood Mine, encompassing approximately 3700 hectares within the present permit boundary, which is the focus of this study. Mining has been carried out at Whitewood since 1963.

It is likely well known to this forum that in Alberta power generation and distribution is handled by regulated private utilities. While much of the power generation activity occurs on Crown lands in the province, there are significant projects which are carried out on private lands.

The power to regulate land use, mining, and reclamation planning on Crown lands in provincial areas rests entirely with the senior level of government. In areas of municipal corporate control, however, the land use planning and the reclamation jurisdictions are separate.

The Whitewood Mine, located in the County of Parkland No. 31, lies within an area in which two jurisdictions have an interest and a responsibility.

Firstly, the Land Surface Conservation and Reclamation Act (1977), is administered by the Development and Reclamation Review Committee (D & R Committee); this body is composed of representatives of several provincial government departments including Alberta Agriculture, Environment, Fish and Wildlife, and Recreation and Parks. The purpose of the D & R Committee is to ensure the reclamation of disturbed lands, following both conceptual long term and more specific short term plans prepared by the Company and submitted to the Committee for approval. Ultimately, when its conditions for reclamation of a given parcel of land have been met (these conditions for reclamation are based upon the provisions of the Act), the D & R Committee issues a Reclamation Certificate, releasing the company from further reponsibility for the restoration and management of that parcel of land.

Secondly, the County of Parkland No. 31 is responsible for planning the surface use of the land and has an interest in the environmental status of the permit area and of adjacent lands.

The County of Parkland operates under the enabling legislation of the Alberta Planning Act (RSA 1980) and attendant legislation. This legislation requires the conformity of the County Plans with the general prescriptions and long range policies of the Regional Plan. The Regional Plan, which has been drafted but not adopted in this area, classifies the Whitewood area as industrial land. This recognition of existing land use is not helpful in identifying appropriate land uses after mining.

The more detailed General Plan and Land Use Bylaws also identify the existing use rather than the potential land uses after mining is complete. In the absence of such long range policy, there is no means of guiding reclamation toward specific land use goals. The Municipal Council of the County has been granted the authority to make binding land use decisions through the enactment and administration of its own General Plan and Land Use By-Laws; the County Council has the authority to approve subdivision and development within its boundaries.

The potential exists for conflict between these two jurisdictions. On one hand, the Land Surface Conservation and Reclamation Act contains the specific requirement that reclamed land shall be restored to a state of usefulness "equal to or greater than" that which existed prior to disturbance. In a similar vein, the County's mandate is to make land use decisions based upon "highest and best use" of the land. The definition of these notions of equal or greater productivity and highest and best land use are subjective and open to interpretation by members of the various administrative bodies.

The private utility company may easily feel somewhat "sandwiched" and unable to please the two jurisdictions at the same time.

An example might best explain the situation. The unmined portion within the permit boundary at Whitewood is largely forested bog, with a reasonably good potential for the support of populations of moose. If productivity for this species is used as the yardstick by which reclamation success is measured, the D & R Committee would require TransAlta to return the disturbed land to a forested bog.

The recreation growth trends in the Edmonton Region, however, may indicate to the County of Parkland that the highest and best use of the post mine area may be for active recreation pursuits.

TransAlta Utilities may, in the meantime, be directing the reclamation of all mined land at Whitewood towards agricultural production, a goal which may or may not prove to be satisfactory to the two regulating agencies.

It is clearly necessary that the land use goals and future designations coincide or parallel the reclamation goals and thus the reclamation activity. There was, in the Whitewood Permit area, an obvious need to coordinate land use and reclamation planning and to rationalize jurisdictional differences prior to reclamation. A planning process was initiated in June 1981.

EPEC Consulting Western Ltd. was retained to manage a team of experts from a number of specialized fields in the preparation of the Plan. Earthscape Consultants jointly coordinated the project and was responsible for interpretation of the matrix methodology and the capability analysis of the site, as well as final report production. Monenco Company Limited provided information concerning the effect of mining upon land characteristics, and devised a method for the assessment of the capability of reclaimed land.

3.0 GOALS, OBJECTIVES, METHODOLOGY

3.1 Goals

The Whitewood Future Land Use Study was initiated with the purpose of developing a land use plan for the Whitewood Permit area after mining was completed. The plan was to be acceptable to the County of Parkland in terms of its mandate and responsibility to direct long term land use in the area. It was to be accepted as input to the Development and Reclamation Committee to the extend that it would establish the basis for setting reclamation guidelines, adjusting practice, and judging results. It was to be acceptable to TransAlta Utilities in the sense that it established the basis for an orderly and cost-efficient reclamation plan.

3.2 Objectives

The objectives of the study incorporate the goals in a more detailed fashion, and are indicated below:

- To prepare plans which reflect the "highest and best use" of the lands before mining occurred.

- To prepare plans which reflect the "highest and best use" of the lands after mining is completed.

- To incorporate into the study a method of identifying and assessing the capability of the lands to sustain the impact of a variety of potential developments.

- To incorporate a method of identifying the suitability of the lands to sustain a new land use.

- To facilitate the cooperation of the responsible agencies in the study area, including TransAlta Utilities and the County of Parkland, in identifynig the opportunities afforded by the land reclamation activity to enhance the final potential of the land for a variety of land uses.

- To integrate into the planning process the professional advice and expert opinions of Government Agencies involved in the reclamation process.

- To provide a study methodology which would maintain a record of both the expert and the non-expert decisions taken during the course of the study. It should be flexible enough that it can be updated in the future as new information is provided.

- To provide the basis for the preparation of the Whitewood Area Structure Plan by the County of Parkland No. 31.

- To provide the basis for the preparation of the Whitewood Development and Reclamation Plan by TransAlta Utilities.

3.3 Methodology

The method developed to achieve these objectives involves the classis approach to problem solving, with few modifications of any significance. The approach involving INVENTORY - ANALYSIS - PLAN is common to many disciplines.

A notable difference to such a method in a Planning System is perhaps the iterative process of feedback, analysis and response which occurs during the decision making process at the end of the initial application of the method. It is the decision-makers, with the technical advice and assistance of the researcher, who decide the final land use allocations in a process of this nature.

The method employed in this study utilized a system of computerized matrices and computer graphics to effect the analysis of inventory data. The method also developed an inventory of the post-mining landscape which formed the basis for post-mine planning.

Steps in the study method are presented graphically in the chart following, and are briefly explained below.

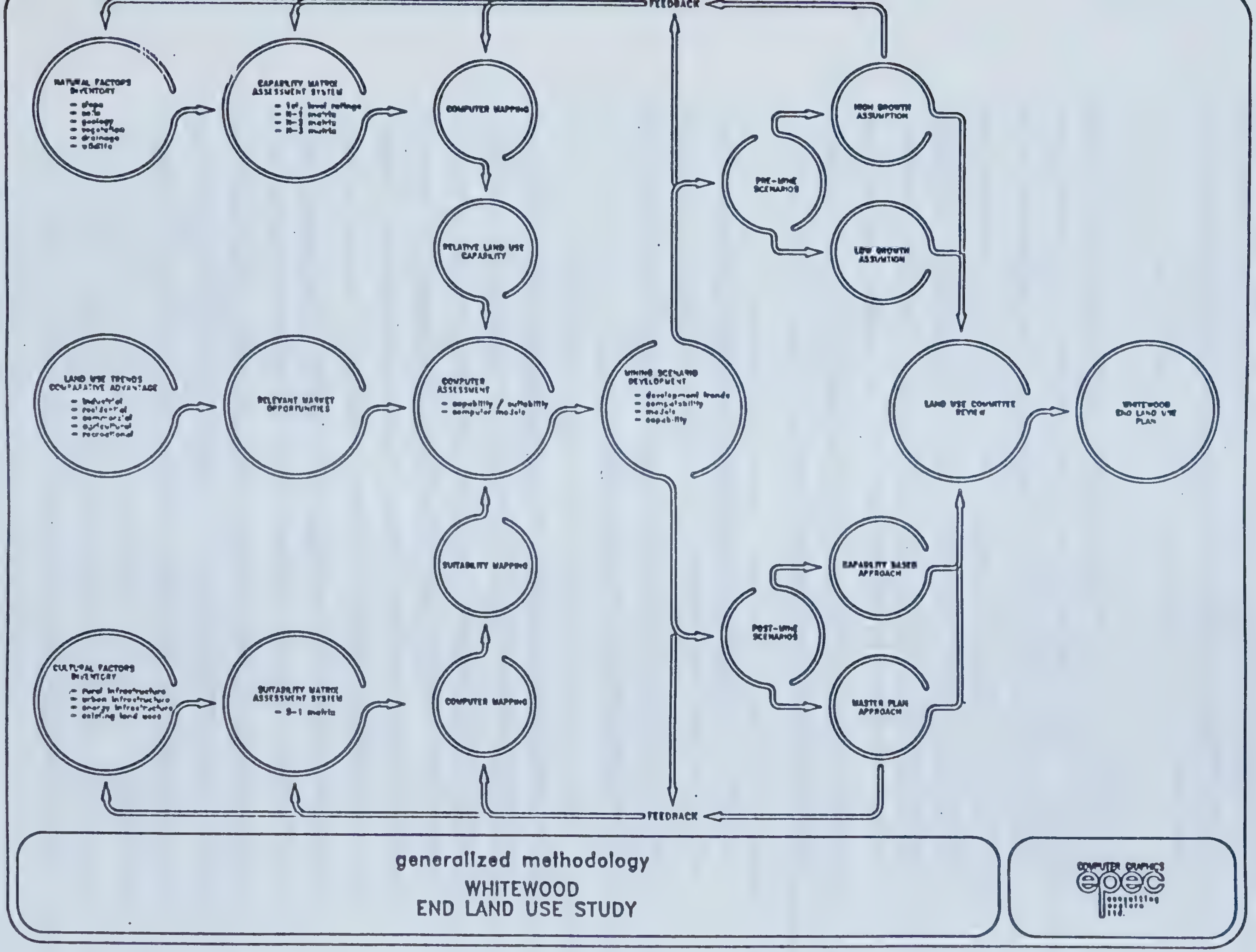
Natural Factors Inventory - an inventory of the slopes, soils, surficial geology, hydrology (surface drainage, water table), vegetation and wildlife in the study area. The inventory was developed by specialist members of the Study Team at a 1:15,000 scale.

Cultural Factors Inventory - an inventory of man-made components of the study area - urban centers, land uses, railway, highway, resort uses, commercial uses, agriculture, pipelines, generation plants, and so on.

Regional Trends Analysis - this basic analysis identified the demand and supply trends in the region for a number of land use categories, concluding with an assessment of the comparitive advantage of the study area relative to other areas in the region for these categories.

A continuum of 107 land uses, representing development from the lowest to the highest intensity, was prepared.

A Suitability matrix was developed to reflect appropriate land use planning criteria. This matrix specified setback distances of the 107 land uses from the components of area infrastructure - railways, roads, pipelines, urban centers, and so on. A computer-generated map of these setbacks could be rendered for each land use.


FEEDBACK
NATURAL FACTORS INVENTORY
- slope
- soils
- geology
- vegetation
- drainage
- wildlife
CAPABILITY MATRIX ASSESSMENT SYSTEM
- 1st. level ratings
- R-1 matrix
- R-2 matrix
- R-3 matrix
COMPUTER MAPPING
RELATIVE LAND USE CAPABILITY
LAND USE TRENDS COMPARATIVE ADVANTAGE
- industrial
- residential
- commercial
- agricultural
- recreational
RELEVANT MARKET OPPORTUNITIES
COMPUTER ASSESSMENT
- capability / suitability
- computer models
MINING SCENARIO DEVELOPMENT
- development trends
- compatability
- models
- capability
PRE-MINE SCENARIOS
HIGH GROWTH ASSUMPTION
LOW GROWTH ASSUMPTION
LAND USE COMMITTEE REVIEW
WHITEWOOD END LAND USE PLAN
SUITABILITY MAPPING
CULTURAL FACTORS INVENTORY
- rural infrastructure
- urban infrastructure
- energy infrastructure
- existing land uses
SUITABILITY MATRIX ASSESSMENT SYSTEM
- S-1 matrix
COMPUTER MAPPING
POST-MINE SCENARIOS
CAPABILITY BASED APPROACH
MASTER PLAN APPROACH
FEEDBACK
COMPUTER GRAPHICS
epec
consulting
western
ltd.

generalized methodology
WHITEWOOD
END LAND USE STUDY

The inventory of Natural Factors was mapped for presentation in two formats, details of which are described in Section 5 of this paper.

The purpose of the computer mapping of the first level ratings was to resolve the existing natural factors to a common typological system which was both relevant to the determination of capability and which would lend itself to comparison and analysis of inventory data. The 0-9 ratings are relative classifications of natural resiliences, adapative response, and/or tolerance to manipulation. In general terms these ratings describe the relative capability of the resource (natural factor) to withstand impact.

A system of matrices was utilized to determine relative capability of the land resource to sustain the impact of each of the 107 land uses. Relative capability maps for each of the 107 land uses could then be produced.

While capability for detail was a goal of the system, 107 land uses were too detailed to allocate in a future land use plan. Twenty-five uses were selected representing the range of scores (and therefore use intensity) from a capability product matrix. These uses were grouped in seven categories. Composite Capability/Suitability maps, developed through a computerized priorizing matrix, were compared for pixel (computer-mapped polygon) frequency and for locational patterns in the land uses. Seven land uses were selected to represent the seven categories identified. A number of individual land uses were identified as being important for future individual analysis.

Finally, land use models were developed by computer. These models indicate the most appropriate areas for a combination of several land uses, or areas which are primarily capable of sustaining a single use category.

The development of post-mine models was preceded by an assessment of the post-mine spoil by Monenco. This assessment, in effect, recreated the natural factors inventory in the post-mine situation. A revised existing land use plan recreated the cultural factors inventory. The computer system was then used to generate the same maps for the post-mine situation.

High and low development scenarios, based on differing regional trends, assumptions, were developed for the pre-mine area. A "capability based" and an "opportunity based" plan was prepared for the post-mine situation.

The "public" process in this exercise involved the reporting and presentation of results to a Committee comprising senior government agencies, corporate represenatives, and the municipal administration. Amendments to land use categories were discussed in Committee, assessed for capability and suitability by the study team, and subsequently reconsidered by the Committee prior to final decision.

4.0 COMPUTERIZED PLANNING SYSTEM

The purpose of this portion of the paper is to explain in sufficient detail the step by step procedure of the Whitewood Future Land Use Study to allow the reader an understanding of the use of a computer system. The grid mode technique existed prior to this study, but the subroutines were developed specifically for this study. A mainframe computer was utilized due to the cost effectiveness for handling the amount of data.

This portion of the paper was developed for excerpting from the Technical Report prepared for the Whitewood Future Land Use Study and is not intended as a document to fully detail the methods or describe the computer programs per se, but to illustrate the value of an Interactive Computerized Planning System.

4.1 Inventory

4.1.1 Introduction

The inventory of Natural Factors is mapped for presentation in two formats. First, each natural factor is mapped by the computer using conventional mapping units as identified by each specialist on the study team. These conventional units describe existing homogenous areas by soil type, dominant vegetation cover and so on.

The second set of maps generated by computer graphically presents the first level ratings assigned by the experts to the inventory categories selected. In this exercise, for example, the ten units (0-9) identified within the vegetation tolerance category would be generated.

The inventory of cultural factors such as existing land uses, amenities, and infrastructure components is completed in order to provide a basis from which policy decisions regarding desirable or "suitable" locations for various potential future land uses might be made.

4.1.2 Factors

The inventory component of the Whitewood Future Land Use Study is primarily a graphic, mapped presentation of the natural and cultural features of the study area.

The natural factors considered relevant for future land use planning included physical resources (slope, soils, geology, surface hydrology), biological resources (vegetation, wildlife), and cultural resources (existing land use, infrastructure, amenities, mine plans).

The inventory of natural factors were reviewed and compiled by individuals specialized in the particular field of study. Each specialist reviewed existing reserach and data in the area, performed basic aerial and field truthing of the data, and prepared inventory mapping on the contour base. These inventory maps were subsequently digitized directly for the computer data base.

4.1.3 First Level Ratings

The digitized plot for each natural factors was reviewed by the specialist. The inventory components for each natural factor were then assigned first level ratings by the specialist.

The first level ratings assigned to the inventory data for the natural factors is a means of ranking inventory units on a 0-9 scale that is a consistent measure of capability between terrain components (such as soils and vegetation). The total different types of map units for a terrain component may be as many as thirty or more but when related to the first level ratings those thirty would be coded to the ten units of the first level rating classification. The first level ratings for each classification be it topsoil trafficability or water table level are ranked so that the best is zero (0) and the worst is nine (9). Therefore, the most trafficable soil units score 0 and the least trafficable score 9. For each classification, all the score numerals are not necessarily unitized for the study area. For example, of the 15 inventory geological units mapped in the Whitewood Study Area only 3, 4, 8, and 9 were utilized for the scoring of compressibility, and only a 0, 5 and 9 for the water table depth where 9 is a water table less than 1m from the surface and 5 is a water table between 1 and 3m from the surface and 0 is greater than 3m from the surface.

The first level ratings for the physical and biological resources system are defined as the following.

Slope - the relative capability rating of precentage slope, where slope rise in vertical elevation is expressed on a percentage of the run in horizontal distance. If the terrain rises 10m in 100m then the percentage slope is 10%. The 0-9 ratings directly apply to the inventory units as identified.

Topsoil Trafficability - the relative capability rating of the topsoil to support movement and the compaction and disturbance associated with that action without causing irreversable damage to the soil based on the Kjeassgarrd method to estiamte trafficability. Profile characteristics and texture are combined to give a cumulative index of overall trafficability.

Erodability - the relative capability rating of the topsoil to withstand the forces of rain, run-off and wind that initiate and continue the erosion process. This erodibility rating is based on the texture, type of Ah (upper humus) horizon and the drainage characteristics of the soil unit.

Agricultural Rating - the relative capability rating of the soil units for agricultural production as a growing medium determined by considering the fertility, drainage, general topography and agri-climate orientation. This rating is a more detailed method adapted from the C.L.I. system of agricultural rating as approved by the Canada Soil Survey Committee.

Profile Permeability - the relative capability rating of the soil profile and underlying materials to allow water to infiltrate or percolate to a lower depth, to move through the profile from the surface and not remain on or near the surface. The profile permeability rating is calculated by correlating the textures through the profile, the amount of organic matter and the shrink-swell potential of the materials.

Profile Trafficability - the relative capability rating of the trafficability of the parent material on which the topsoil has been formed identified in the surficial geological and geological units as inventoried. In this rating the trafficability and resultant compaction and disturbance is as resulting from vehicular movement.

Compressibility - the relative rating of the surficial geological deposits and geological bedrock unit to withstand loading wherefor loads are weights being exerted on the material. The compressibility is a geotechnical rating determined by considering the existing consolidation situation, the texture and frostheave potential of the materials of the unit.

Water Table Level - the relative capability rating of the depth to water table from the hydrology mapping where poorly drained and standing water bodies are mapped and from the geological mapping for units probably having high or intermittantly high water tables. No verification by test hole drilling to determine depth to water table has been conducted in the study area.

Vegetation Tolerance - the relative capability rating of the vegetation units to disturbance. The sensitivity of the units is given based on successional stage, presence of mosses and lichens, amount of grass cover and, to a less extent, aspect. The most sensitive areas are the least capable and score 9.

With each of the above categories, the appropriate specialist assigned first level ratings along the 0-9 continuum. In all categories the most capable is 0 and least capable is 9.

Cultural factors, those man-made aspects of the study area, have not been assigned first level ratings. In similar fashion, the wildlife component of the study area has been retained as a residual, rather than being incorporated into the first level rating.

4.2 Analysis

4.2.1 Introduction

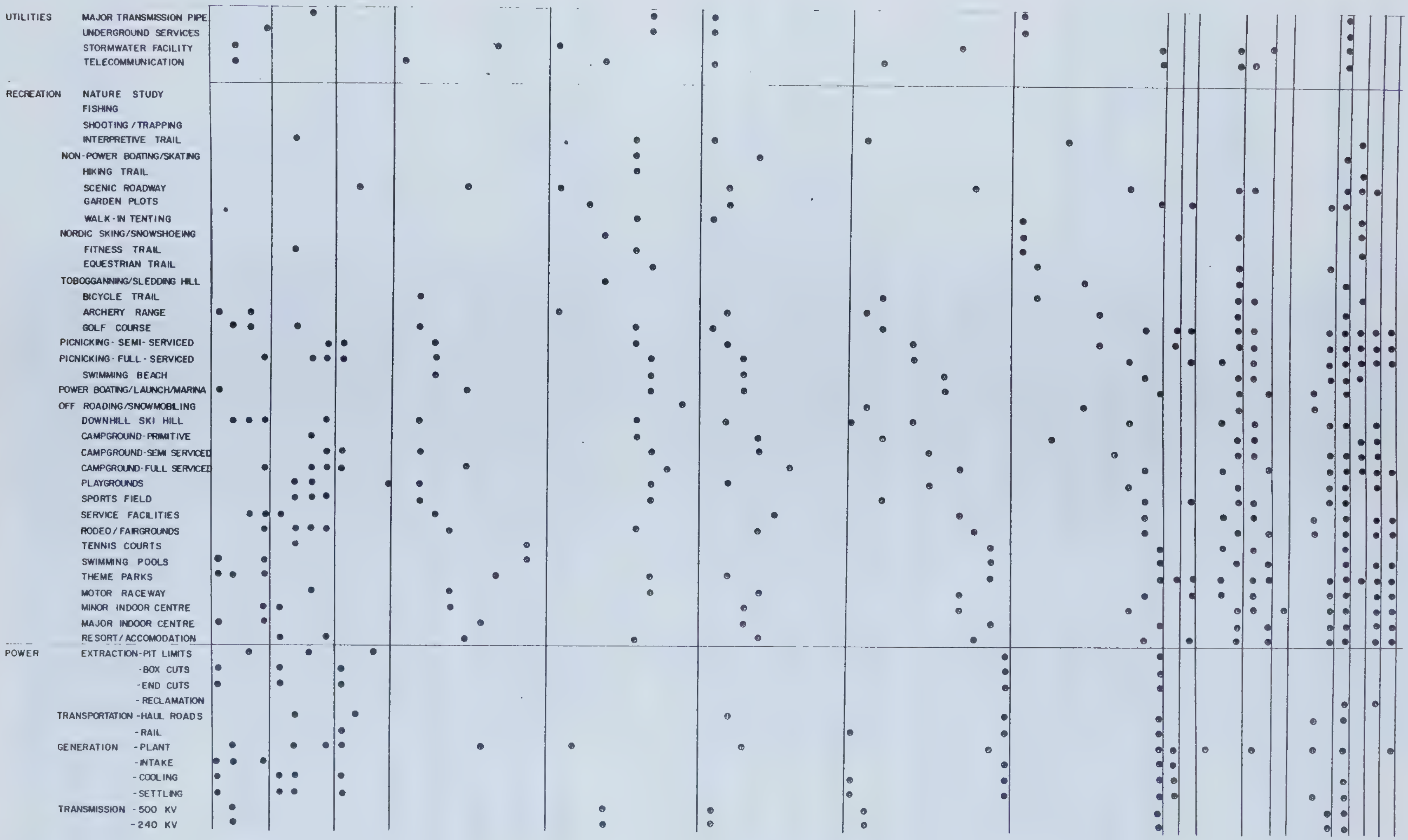
The process of analysis is initially disaggregated into two streams: the natural factors are analyzed to achieve a measure of the capability of the study area to sustain various uses; the cultural factors are analyzed to achieve a measure of the suitability of locating given land uses in a particular area.

The value of the computer process to analysis lies in the flexibility and the speed at which the computer can generate information regarding effects of land use relative to suitability and capability in the study area. It also lends itself to a process of ongoing analysis and updating of information based upon feedback from past decisions.

The analysis of inventory data is achieved through the development of a system of matrices through which information is programmed and stored by computer. A software package manipulates the information to achieve the matrix objectives, and finally relates the matrix analysis to the computer mapped inventory data to produce a new mapped composite. The products of the analysis can be used along with regional trends in development to evaluate the future potential of the study area.

The list of land uses in this methodology has been developed to reflect as comprehensively as is feasible the range of potential land uses which one might consider for an area. In this manner, the total range from highest impact to lowest impact uses has been included in the analysis. This does not imply that all uses should be considered for the area, but rather allows the grouping of uses by ranges of impact and allows future analysis to develop composite mapping of capability and suitability for any given single land use. It can therefore be used as an input in the site selection process or an indicator of required mitigative measures or environmental difficulties relative to a given site.

Within the N-1 Matrix the relative degree of environmental action which is implied by each land use is recorded by a dot in the appropriate cell.



WHITEWOOD / HIGHVALE FUTURE LAND USE STUDY

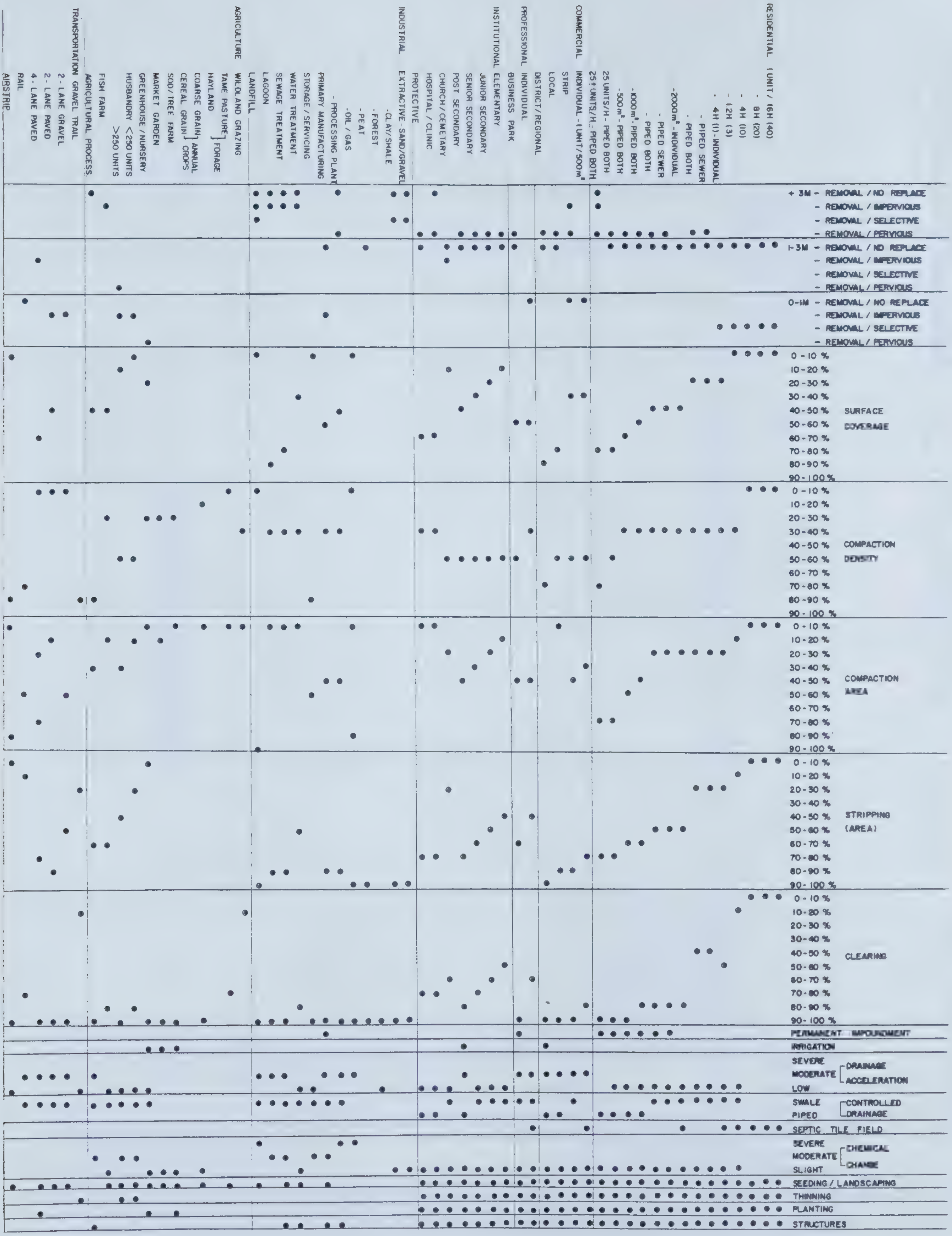
COUNTY OF PARKLAND NO 31

TransAlta Utilities Corporation

epec consulting western ltd.

Earthscape Limited
Landscape Architecture & Resource Consultants

N1


RESIDENTIAL 1 UNIT / 16H (40)
- 8H (20)
- 4H (10)
- 12H (3)
- 4H (1) - INDIVIDUAL
- PIPED SEWER
- PIPED BOTH
-2000m² - INDIVIDUAL
- PIPED SEWER
- PIPED BOTH
-1000m² - PIPED BOTH
-500m² - PIPED BOTH
25 UNITS/H - PIPED BOTH
25+UNITS/H - PIPED BOTH
COMMERCIAL INDIVIDUAL - 1 UNIT/500m²
STRIP
LOCAL
DISTRICT/REGIONAL
PROFESSIONAL INDIVIDUAL
BUSINESS PARK
INSTITUTIONAL ELEMENTARY
JUNIOR SECONDARY
SENIOR SECONDARY
POST SECONDARY
CHURCH / CEMETARY
HOSPITAL / CLINIC
PROTECTIVE
INDUSTRIAL EXTRACTIVE - SAND/GRAVEL
-CLAY/SHALE
-FOREST
-PEAT
-OIL / GAS
- PROCESSING PLANT
PRIMARY MANUFACTURING
STORAGE / SERVICING
WATER TREATMENT
SEWAGE TREATMENT
LAGOON
LANDFILL
AGRICULTURE WILD AND GRAZING
TAME PASTURE
HAYLAND
FORAGE
COARSE GRAIN
CEREAL GRAIN
ANNUAL CROPS
SOD/TREE FARM
MARKET GARDEN
GREENHOUSE / NURSERY
HUSBANDRY <250 UNITS
>250 UNITS
FISH FARM
AGRICULTURAL PROCESS.
TRANSPORTATION GRAVEL TRAIL
2 - LANE GRAVEL
2 - LANE PAVED
4 - LANE PAVED
RAIL
AIRSTRIP
+3M - REMOVAL / NO REPLACE
- REMOVAL / IMPERVIOUS
- REMOVAL / SELECTIVE
- REMOVAL / PERVIOUS
1-3M - REMOVAL / NO REPLACE
- REMOVAL / IMPERVIOUS
- REMOVAL / SELECTIVE
- REMOVAL / PERVIOUS
0-1M - REMOVAL / NO REPLACE
- REMOVAL / IMPERVIOUS
- REMOVAL / SELECTIVE
- REMOVAL / PERVIOUS
0 - 10 %
10 - 20 %
20 - 30 %
30 - 40 %
40 - 50 %
50 - 60 %
60 - 70 %
70 - 80 %
80 - 90 %
90 - 100 %
SURFACE COVERAGE
COMPACTION DENSITY
COMPACTION AREA
STRIPPING (AREA)
CLEARING
PERMANENT IMPOUNDMENT
IRRIGATION
SEVERE
MODERATE
LOW
DRAINAGE ACCELERATION
SWALE
PIPED
CONTROLLED DRAINAGE
SEPTIC TILE FIELD
SEVERE
MODERATE
SLIGHT
CHEMICAL CHANGE
SEEDING / LANDSCAPING
THINNING
PLANTING
STRUCTURES

	0	10	10	10	1 2 3 4 5 6 7 8 9 10	0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0			10				0					
	1	9	9	9	.9 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.1 9	.25 .5 .75 1 1.25 1.5 1.75 2 2.25 2.5	.25 .5 .75 1 1.25 1.5 1.75 2 2.25 2.5			9				1					
	2	8	8	8	.8 1.6 2.4 3.2 4 4.8 5.6 6.4 7.2 8	.5 1 1.5 2 2.5 3 3.5 4 4.5 5	.5 1 1.5 2 2.5 3 3.5 4 4.5 5			8				2					
	3	7	7	7	.7 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 7	.75 1.5 2.25 3 3.75 4.5 5.25 6 6.75 7.5	.75 1.5 2.25 3 3.75 4.5 5.25 6 6.75 7.5			7				3					
	4	6	6	6	.6 1.2 1.8 2.4 3 3.6 4.2 4.8 5.4 6	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10			6				4					
	5	5	5	5	.5 1 1.5 2 2.5 3 3.5 4 4.5 5	1 2 3 4 5 6 7 8 9 10	1 2 3 4 5 6 7 8 9 10			5				5					
	6	4	4	4	.4 .8 1.2 1.6 2 2.4 2.8 3.2 3.6 4	.9 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.1 9	.9 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.1 9			4				4					
	7	3	3	3	.3 .6 .9 1.2 1.5 1.8 2.1 2.4 2.7 3	.8 1.6 2.4 3.2 4 4.8 5.6 6.4 7.2 8	.8 1.6 2.4 3.2 4 4.8 5.6 6.4 7.2 8			3				3					
	8	2	2	2	.2 .4 .6 .8 1 1.2 1.4 1.6 1.8 2	.7 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 7	.7 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 7			2				2					
	9	1	1	1	.1 .2 .3 .4 .5 .6 .7 .8 .9 1	.6 1.2 1.8 2.4 3.0 3.6 4.2 4.8 5.4 6	.6 1.2 1.8 2.4 3.0 3.6 4.2 4.8 5.4 6			1				1					
PROFILE TRAFFICABILITY	0																		
	1																		
	2																		
	3																		
	4																		
	5										1								
	6										2								
	7										3								
	8										4								
	9										3								
COMPRESSIBILITY	0	10	10																
	1	9	9																
	2	8	8																
	3	7	7																
	4	6	6																
	5	5	5																
	6	4	4																
	7	3	3																
	8	2	2																
	9	1	1																
WATER TABLE LEVEL +3M	0									10				2.5					
	1																		
	2																		
	3																		
	4																		
	5																		
1-3M	6									7.5	5			5					
INTERMITTENT CREEK	7									2.5	2.5								
0-1M	8									5	7.5			10					
OPEN WATER / LAKES	9																		
VEGETATION TOLERANCE	0					0 0 0 0 0 0 0 0 0 0			.1 .2 .3 .4 .5 .6 .7 .8 .9 10						10 .5 .1				
	1					0 1 2 3 4 5 6 7 8 9			.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 10						10 1 .2				
	2					1 2 3 4 5 6 7 8 9 10			.3 .6 .9 1.2 1.5 1.8 2.1 2.4 2.7 10						10 1.5 .3				
	3					2 3 4 5 6 7 8 9 10 10			.4 .8 1.2 1.6 2.0 2.4 2.8 3.2 3.6 10						10 2 .4				
	4					3 4 5 6 7 8 9 10 10 10			.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 10						10 2.5 .5				
	5					4 5 6 7 8 9 10 10 10 10			.6 1.2 1.8 2.4 3.0 3.6 4.2 4.8 5.4 10						10 3 .6				
	6					5 6 7 8 9 10 10 10 10 10			.7 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 10						10 3.5 .7				
	7					6 7 8 9 10 10 10 10 10 10			.8 1.6 2.4 3.2 4.0 4.8 5.6 6.4 7.2 10						10 4 .8				
	8					7 8 9 10 10 10 10 10 10 10			.9 1.8 2.7 3.6 4.5 5.4 6.3 7.2 8.1 10						10 4.5 .9				
	9					8 9 10 10 10 10 10 10 10 10			1 2 3 4 5 6 7 8 9 10						10 5 1				

WHITEWOOD / HIGHVALE FUTURE LAND USE STUDY

COUNTY OF PARKLAND NO. 31

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N2

IMPACT MATRIX

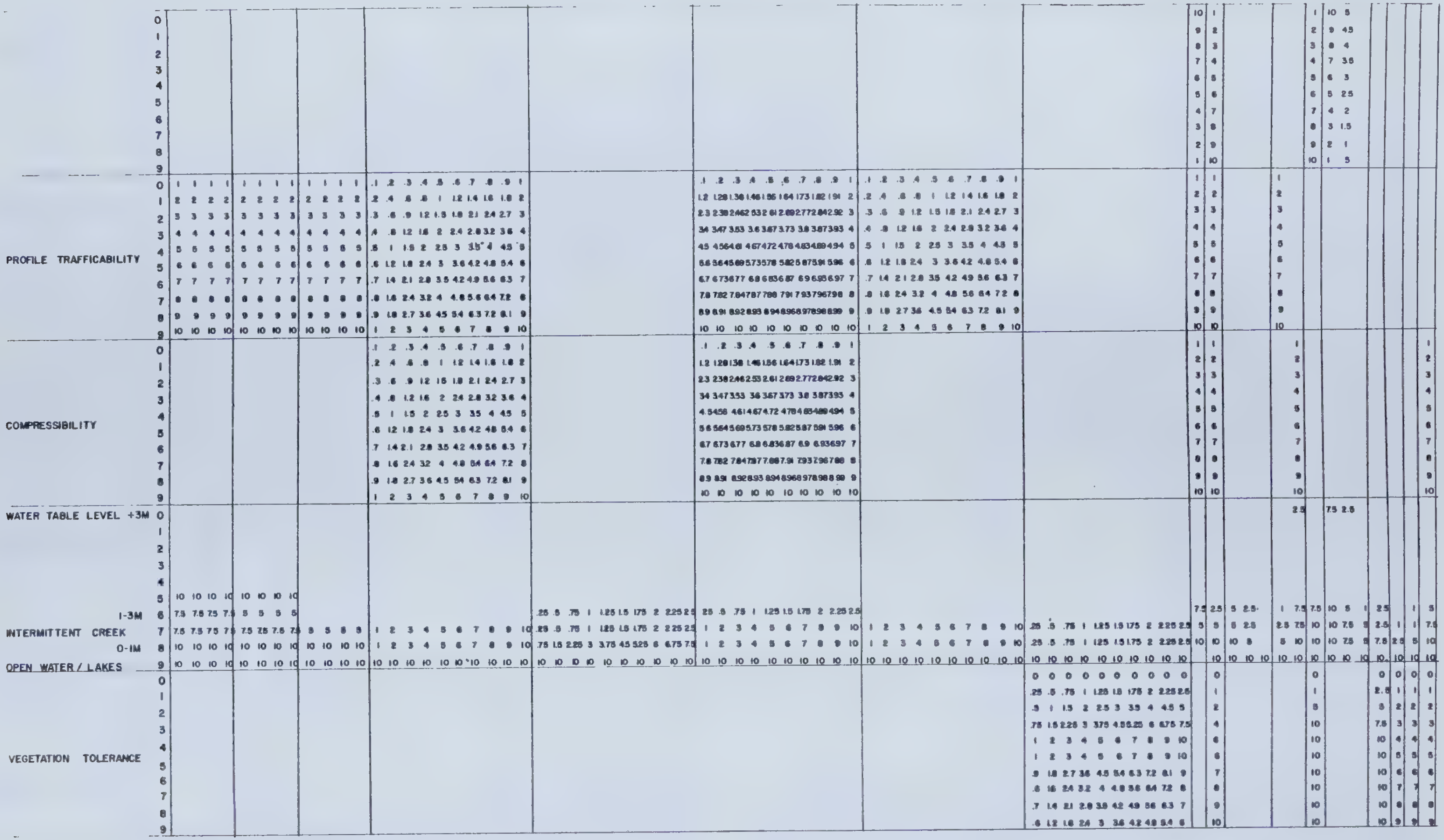
		+ 3M – REMOVAL / NO REPLACE	– REMOVAL / IMPERVIOUS	– REMOVAL / SELECTIVE	– REMOVAL / PERVIOUS	1-3M – REMOVAL / NO REPLACE	– REMOVAL / IMPERVIOUS	– REMOVAL / SELECTIVE	– REMOVAL / PERVIOUS	0-1M – REMOVAL / NO REPLACE	– REMOVAL / IMPERVIOUS	– REMOVAL / SELECTIVE	– REMOVAL / PERVIOUS
SLOPE	0	1				.5				1			
	1	2				1				2			
	2	3				1.5				3			
	3	4				2				4			
	4	5				2.5				5			
	5	6				3				6			
	6	7				3.5				7			
	7	8				4				8			
	8	9				4.5				9			
	9	10				5				1			
TOPSOIL TRAFFICABILITY	0				10				10				1
	1				9				9				.9
	2				8				8				.8
	3				7				7				.7
	4				6				6				.6
	5				5				5				.5
	6				4				4				.4
	7				3				3				.3
	8				2				2				.2
	9				1				1				.1
ERODIBILITY	0		10				10				10		
	1		9				9				9		
	2		8				8				8		
	3		7				7				7		
	4		6				6				6		
	5		5				5				5		
	6		4				4				4		
	7		3				3				3		
	8		2				2				2		
	9		1				1				1		
AGRICULTURAL RATING	0		10		5		10		5		10		5
	1		9		4		9		4		9		4
	2		8		3		8		3		8		3
	3		7		2		7		2		7		2
	4		6		1		6		1		6		1
	5		5				5				5		
	6		4				4				4		
	7		3				3				3		
	8		2				2				2		
	9		1				1				1		
REVEGETATION RATING	0												
	1												
	2												
	3												
	4												
	5												
	6												
	7												
	8												
	9												

		SURFACE COVERAGE 0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %	80-90 %	90-100 %	COMPACTION DENSITY 0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %	80-90 %	90-100 %
SLOPE	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
TOPSOIL TRAFFICABILITY	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
ERODIBILITY	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
AGRICULTURAL RATING	0											1	2	3	4	5	6	7	8	9	10
	1											.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9
	2											.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8
	3											.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7
	4											.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6
	5											.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5
	6											.4	.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4
	7											.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3
	8											.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2
	9											.1	.2	.3	.4	.5	.6	.7	.8	.9	1
REVEGETATION RATING	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				

		COMPACTION AREA 0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %	80-90 %	90-100 %	STRIPPING (AREA) 0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %	80-90 %	90-100 %
SLOPE	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
TOPSOIL TRAFFICABILITY	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
ERODIBILITY	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
AGRICULTURAL RATING	0	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	1	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	2	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	3	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	4	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	5	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	6	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	7	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	8	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
	9	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
REVEGETATION RATING	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				

		CLEARING 0-10 %	10-20 %	20-30 %	30-40 %	40-50 %	50-60 %	60-70 %	70-80 %	80-90 %	90-100 %
SLOPE	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
TOPSOIL TRAFFICABILITY	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
ERODIBILITY	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
	1	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2
	2	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3
	3	.4	.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4
	4	.5	1	1.5	2	2.5	3	3.5	4	4.5	5
	5	.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6
	6	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7
	7	.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8
	8	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9
	9	1	2	3	4	5	6	7	8	9	10
AGRICULTURAL RATING	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
REVEGETATION RATING	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										

		PERMANENT IMPOUNDMENT	IRRIGATION	DRAINAGE ACCELERATION SEVERE	MODERATE	LOW	CONTROLLED DRAINAGE SWALE	PIPED	SEPTIC TILE FIELD	CHEMICAL CHANGE SEVERE	MODERATE	SLIGHT	SEEDING / LANDSCAPING	THINNING	PLANTING	STRUCTURES
SLOPE	0															
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
	9															
TOPSOIL TRAFFICABILITY	0															
	1															
	2															
	3															
	4															
	5		1													
	6		2													
	7		3													
	8		4													
	9		5													
ERODIBILITY	0			10	5.5	1	1							5		
	1			10	6	2	2							1		
	2			10	6.5	3	3							1.5		
	3			10	7	4	4							2		
	4			10	7.5	5	5							2.5		
	5			10	8	6	6							3		
	6			10	8.5	7	7							3.5		
	7			10	9	8	8							4		
	8			10	9.5	9	9							4.5		
	9			10	10	10	10							5		
AGRICULTURAL RATING	0			5	2.5					10	5					
	1			4	2					9	4.5					
	2			3	1.5					8	4					
	3			2	1					7	3.5					
	4			1	.5					6	3					
	5									5	2.5					
	6									4	2					
	7									3	1.5					
	8									2	1					
	9									1	.5					
REVEGETATION RATING	0															
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
	9															


PROFILE TRAFFICABILITY
COMPRESSIBILITY
WATER TABLE LEVEL +3M
INTERMITTENT CREEK
1-3M
0-1M
OPEN WATER / LAKES
VEGETATION TOLERANCE
0
1
2
3
4
5
6
7
8
9

WHITEWOOD / HIGHVALE FUTURE LAND USE STUDY

COUNTY OF PARKLAND NO. 31
TransAlta Utilities Corporation

epec consulting western ltd.
ENVIRONMENTAL PLANNING AND ENGINEERING CONSULTANTS
Earthscape Limited
Landscape Architecture & Resource Consultants

N3
SITE SELECTION MATRIX

		+ 3M – REMOVAL / NO REPLACE	– REMOVAL / IMPERVIOUS	– REMOVAL / SELECTIVE	– REMOVAL / PERVIOUS	1-3M – REMOVAL / NO REPLACE	– REMOVAL / IMPERVIOUS	– REMOVAL / SELECTIVE	– REMOVAL / PERVIOUS	0-1M – REMOVAL / NO REPLACE	– REMOVAL / IMPERVIOUS	– REMOVAL / SELECTIVE	– REMOVAL / PERVIOUS	SURFACE COVERAGE 0 - 10 %	10 - 20 %	20 - 30 %	30 - 40 %	40 - 50 %	50 - 60 %	60 - 70 %	70 - 80 %	80 - 90 %	90 - 100 %
SLOPE	0	1	1	1	1	1	1	1	1	.5	.5	.5	.5	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
	1	2	2	2	2	2	2	2	2	1	1	1	1	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2
	2	3	3	3	3	3	3	3	3	1.5	1.5	1.5	1.5	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3
	3	4	4	4	4	4	4	4	4	2	2	2	2	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4
	4	5	5	5	5	5	5	5	5	2.5	2.5	2.5	2.5	.5	1	1.5	2	2.5	3	3.5	4	4.5	5
	5	6	6	6	6	6	6	6	6	3	3	3	3	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6
	6	7	7	7	7	7	7	7	7	3.5	3.5	3.5	3.5	.7	1.4	2.1	2.8	3.5	4.2	4.7	5.6	6.3	7
	7	8	8	8	8	8	8	8	8	4	4	4	4	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8
	8	9	9	9	9	9	9	9	9	4.5	4.5	4.5	4.5	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9
	9	10	10	10	10	10	10	10	10	5	5	5	5	1	2	3	4	5	6	7	8	9	10
TOPSOIL TRAFFICABILITY	0																						
	1																						
	2																						
	3																						
	4																						
	5																						
	6																						
	7																						
	8																						
	9																						
ERODIBILITY	0																						
	1																						
	2																						
	3																						
	4																						
	5																						
	6																						
	7																						
	8																						
	9																						
AGRICULTURAL RATING	0																						
	1																						
	2																						
	3																						
	4																						
	5																						
	6																						
	7																						
	8																						
	9																						
REVEGETATION RATING	0																						
	1																						
	2																						
	3																						
	4																						
	5																						
	6																						
	7																						
	8																						
	9																						

		COMPACTION DENSITY 0 - 10 %	10 - 20 %	20 - 30 %	30 - 40 %	40 - 50 %	50 - 60 %	60 - 70 %	70 - 80 %	80 - 90 %	90 - 100 %	COMPACTION AREA 0 - 10 %	10 - 20 %	20 - 30 %	30 - 40 %	40 - 50 %	50 - 60 %	60 - 70 %	70 - 80 %	80 - 90 %	90 - 100 %
SLOPE	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
	1	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2
	2	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3
	3	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4
	4	.5	1	1.5	2	2.5	3	3.5	4	4.5	5	.5	1	1.5	2	2.5	3	3.5	4	4.5	5
	5	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6
	6	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7
	7	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8
	8	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9
	9	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
TOPSOIL TRAFFICABILITY	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1										
	1	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2										
	2	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3										
	3	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4										
	4	.5	1	1.5	2	2.5	3	3.5	4	4.5	5										
	5	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6										
	6	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7										
	7	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8										
	8	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9										
	9	1	2	3	4	5	6	7	8	9	10										
ERODIBILITY	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
AGRICULTURAL RATING	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
REVEGETATION RATING	0																				
	1																				
	2																				
	3																				
	4																				
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	7																				
	8																				
	9																				

		STRIPPING (AREA) 0 - 10 %	10 - 20 %	20 - 30 %	30 - 40 %	40 - 50 %	50 - 60 %	60 - 70 %	70 - 80 %	80 - 90 %	90 - 100 %	CLEARING 0 - 10 %	10 - 20 %	20 - 30 %	30 - 40 %	40 - 50 %	50 - 60 %	60 - 70 %	70 - 80 %	80 - 90 %	90 - 100 %
SLOPE	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
	1	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2
	2	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3
	3	.4	.8	1.2	1.6	2	2.1	2.8	3.2	3.6	4	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4
	4	.5	1	1.5	2	2.5	3	3.5	4	4.5	5	.5	1	1.5	2	2.5	3	3.5	4	4.5	5
	5	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6
	6	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7
	7	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8
	8	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9
	9	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
TOPSOIL TRAFFICABILITY	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1	.1	.2	.3	.4	.5	.6	.7	.8	.9	1
	1	.2	.4	.6	.8	1	1.2	1.4	1.6	1.8	2	1.2	1.28	1.38	1.46	1.56	1.64	1.73	1.82	1.91	2
	2	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3	2.3	2.38	2.46	2.53	2.61	2.69	2.77	2.84	2.92	3
	3	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4	3.4	3.47	3.53	3.6	3.67	3.73	3.8	3.87	3.93	4
	4	.5	1	1.5	2	2.5	3	3.5	4	4.5	5	4.5	4.56	4.61	4.67	4.72	4.78	4.83	4.89	4.94	5
	5	.6	1.2	1.8	2.4	3	3.6	4.2	4.8	5.4	6	5.6	5.64	5.69	5.73	5.78	5.82	5.87	5.91	5.96	6
	6	.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7	6.7	6.73	6.77	6.8	6.83	6.87	6.9	6.93	6.97	7
	7	.8	1.6	2.4	3.2	4	4.8	5.6	6.4	7.2	8	7.8	7.82	7.84	7.87	7.89	7.91	7.93	7.96	7.98	8
	8	.9	1.8	2.7	3.6	4.5	5.4	6.3	7.2	8.1	9	8.9	8.91	8.92	8.93	8.94	8.96	8.97	8.98	8.99	9
	9	1	2	3	4	5	6	7	8	9	10	10	10	10	10	10	10	10	10	10	10
ERODIBILITY	0	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5										
	1	.1	.2	.3	.4	.5	.6	.7	.8	.9	1										
	2	.15	.3	.45	.6	.75	.90	1.05	1.2	1.35	1.5										
	3	.2	.4	.6	.8	1.0	1.2	1.4	1.6	1.8	2										
	4	.25	.5	.75	1.0	1.25	1.5	1.75	2	2.25	2.5										
	5	.3	.6	.9	1.2	1.5	1.8	2.1	2.4	2.7	3										
	6	.35	.7	1.05	1.4	1.75	2.1	2.45	2.8	3.15	3.5										
	7	.4	.8	1.2	1.6	2	2.4	2.8	3.2	3.6	4										
	8	.45	.9	1.35	1.8	2.25	2.7	3.15	3.6	4.05	4.5										
	9	.5	1	1.5	2	2.5	3	3.5	4	4.5	5										
AGRICULTURAL RATING	0																				
	1																				
	2																				
	3																				
	4																				
	5																				
	6																				
	7																				
	8																				
	9																				
REVEGETATION RATING	0																				
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	8																				
	9																				

		PERMANENT IMPOUNDMENT	IRRIGATION	DRAINAGE ACCELERATION SEVERE	MODERATE	LOW	CONTROLLED DRAINAGE SWALE	PIPED	SEPTIC TILE FIELD	CHEMICAL CHANGE SEVERE	MODERATE	SLIGHT	SEEDING / LANDSCAPING	THINNING	PLANTING	STRUCTURES
SLOPE	0	1	1	10	5		.5	1	1				1	.5	.5	1
	1	2	2	9	4.5		1	2	2				2	1	1	2
	2	3	3	8	4		1.5	3	3				3	1.5	1.5	3
	3	4	4	7	3.5		2	4	4				4	2	2	4
	4	5	5	6	3		2.5	5	5				5	2.5	2.5	5
	5	6	6	5	2.5		3	6	6				6	3	3	6
	6	7	7	4	2		3.5	7	7				7	3.5	3.5	7
	7	8	8	3	1.5		4	8	8				8	4	4	8
	8	9	9	2	1		4.5	9	9				9	4.5	4.5	9
	9	10	10	1	.5		5	10	10				10	5	5	10
TOPSOIL TRAFFICABILITY	0		1										1	.5	.5	
	1		2										2	1	1	
	2		3										3	1.5	1.5	
	3		4										4	2	2	
	4		5										5	2.5	2.5	
	5		6										6	3	3	
	6		7										7	3.5	3.5	
	7		8										8	4	4	
	8		9										9	4.5	4.5	
	9		10										10	5	5	
ERODIBILITY	0			1	.75	.5	1						1		1	
	1			2	1.5	1	2						2		2	
	2			3	2.25	1.5	3						3		3	
	3			4	3	2	4						4		4	
	4			5	3.75	2.5	5						5		5	
	5			6	4.5	3	6						6		6	
	6			7	5.25	3.5	7						7		7	
	7			8	6	4	8						8		8	
	8			9	6.75	4.5	9						9		9	
	9			10	7.5	5	10						10		10	
AGRICULTURAL RATING	0												1		1	
	1												2		2	
	2												3		3	
	3												4		4	
	4												5		5	
	5												6		6	
	6												7		7	
	7												8		8	
	8												9		9	
	9												10		10	
REVEGETATION RATING	0															
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
	9															

The second set of matrices, the N-2 and N-3 matrices, record in a numerical fasion the relative negative effects and interrelationships between the natural factors, which are expressed as first level ratings, and the environmental actions.

Once programmed into the computer system, these matrices can be quickly aggregated electronically. Conceptually, the process involves the overlay of the N-1 matrix on the N-2 and N-3 matrices respectively. The score indicated in the appropriate cell of the N-2 or N-3 matrix (i.e. the cell for which a dot score has been indicated on the N-1 matrix above it) is culled out, and the aggregate of the scores in all cells flagged for a given land use in the N-1 matrix are aggregated across the relevant row. This aggregate for all land uses forms the N-4, N-5 or N-6 matrix.

4.2.2 Capability Analysis

Capability is defined as the relative ability of the natural resource to withstand the impact of a land use, or its resilience in adapting to the impact of a land use. The overall objective of the capability matrix system is to determine the intensity of the impact of each use relative to each natural factor in the study area.

The capability system is a three dimensional matrix exercise. The first matrix (N-1) in the system involves the determination of the environmental action implied by a given land use. The second matrices (N-2 and N-3) in the system relates the inherent capability of the natural resource to sustain an environmental action. The third matrices in the system aggregates the total effect of the given land use on the existing land resource (N-4, N-5 and N-6). From this resultant matrices one can group land uses into impact categories to determine which areas are capable of sustaining various types of land uses.

4.2.2.1 N-1 Matrix

The N-1 matrix lists the land uses down the vertical x-axis and the environmental actions across the horizontal y-axis. This matrix records the study team estimates of the degree of environmental action implied by the land use under consideration. For a given land use, therefore, the amount of excavation and type of material replaced, the area covered by an impermeable surface in the density of compaction where 100% is optimum density, the percentage increase in the area compacted (relative the optimum density), the area stripped, the area cleared, permanent impoundment, irrigation, drainage acceleration, controlled drainage systems (swales or pipes), septic tile fields, chemical change, seeding, cultivating, thinning, planting, is estimated on the basis of the experience of the study team.

The term Environmental Actions is used in this study to describe the actions or processes involving the physical manipulation or modification of the landscape required in order to develop or maintain a use of the land. For each land use considered within the N-1 matrix there is a set of environmental actions which would occur if that land use were implemented.

In general, the environmental actions which are listed on the Capability Matrices are arranged in order from the most involved or intense actions to the least intense action. Thus Excavation/Extraction is the first of the environmental actions. Within each environmental action category, however, the amount or degree of the action is arranged from least to highest. For example, within the environmental action "Clearing", there is a continuum from 0-10% to 90-100%.

The environmental actions which are generally considered for each land use are designated by a dot. The matrix is scored based on the professional experience of the team and input by the committee. The percentages indicated for each use are average estimates of the actions involved. The percentage for each use may vary for specific examples, and in more detailed planning and design applications of the system, case studies of existing developments for one use could be analyzed.

4.2.2.2 N-2 Matrix - Impact Assessment

The N-2 matrix is an impact assessment matrix where the horizontal y-axis across the upper column listing the environmental actions have been assessed scores for the affect (or impact) on the natural factors listed as first level ratings down the vertical x-axis. The scoring is based on the assumption that the environmental action has been implemented and the resultant impact on the natural factor rating is the indication of the type and intensity of the impact. Impact traditionally infers a negative situation that requires mtigative measures. The scroing in this matrix system is cmoprehensive in respect to the negative reductions in capability of the natural factors. The types of impacts scored as numerals represent negative impacts on the matrix, relationships scored as 0 with no numerals represents that no impact exists, or that the capability is improved and affects a positive impact.

The N-2 impact has been developed in an interdisciplinary team approach. In this matrix the specialists on the study team have assigned relative numerical values where each environmental action negatively impacts upon each first level rating of the natural factors. The question answered by the specialist, therefore, in compiling this matrix is "if the following environmental action occurs, how does that action affect the unit upon which it occurs?"

An example of the logic used in this matrix is as follows:

> The environmental action of compacting to an optimum density on area impacts the agricultural rating irregardless of the rating that exists. The soil specialist has, therefore, scores all first level ratings, from 0 through 9, with a relative negative impact score of 10 for 100% of the area compacted, where 10 indicates the

highest negative impact on the continuum. The highest native impact is scores as 10 (ten) and reduced relative impacts range to decimals greater than 0 (zero).

The negative impacts have been described according to the rationale of the affect of the action on the first level ratings. The other scoring where no numerals are indicated implies a 0 (zero) or no negative impact. The other types of impacts are; positive or improvements to the rating, or no change to the particular ratings by the action. For purposes of clarification the types of impacts are outlined as follows:

Negative Impact - a negative impact decreases the capability of the natural resource, creating a situation where the resource is less capable than it existed before the action occurred. The impacted area may require greater than normal management practices to mitigate problems, depending on the extent of the impact. There are four types of negative impacts scored in the N-2 Matrix:

a) Highest Impact on the Least Capable Rating
The action impacts the least capable rating most severely, creating an unstable situation as indicated in the scoring of the impact of excavation with no replacement on slope ratings. The scoring of the impact of clearing area on the erodibility rating indicates that the most erodible soils (9) experience the highest impact, while the least erodible experience the least, there-

fore a direct proportional relationship of clearing area to the erodibility capability rating exists. The system is qualified however in that clearing 50% of an area in a clear cut method for a given erodibility would probably require more intense erosion management than clearing 50% of an area of the same erodibility rating in a strip cut method or pocket cut method where 10 pockets of 5% each were cleared within the same total area.

b) Highest Impact on the Most Capable Reading

The action impacts the highest capability rating most severely and descreases in impact on lesser capability rating proportionally. This scoring indicates that the action creates a situation directly opposite to the objective or definition of the capability category. Actions which involve the addition of imported or foreign materials such as excavation where replacement is impervious material and covering the surface with an impermeable layer both impaact the profile permeability. The existing profile which is most permeable is impeded the most, while the least permeable was more closely rated to the new impermeable situation.

c) Ratings no all Impacted on Propotional Basis

The scoring of the impact of compaction density and compaction area on profile permeability relates directly to the characteristics of the inventory units which the first level ratings represent. The higher permeability ratings are coarse grained materials which increase in impact when compacted. The middle ratings 4 and 5 are fine grained materials which exist in a relatively loose condition, when compacted these units are impacted to the highest extent. The lower rated units are fine grained but increase in compaction in the existing state, and thus are not as severely impacted.

d) Highest Impact on all Agriculture Ratings from Actions which remove the Capability

The agricultural rating rates the inherent capability of the existing resource for crop production. The impact of compacting an area to optimum density mechanically and replacing the topsoil is the same impact as stripping the topsoil. If the total area is acted upon th impact or consequence is that crops cannot grow, irrespective of the original rating whether it was good or poor.

e) Highest Impact on all Vegetation Ratings when Totally Cleared with Proportional Decrease Based on Capability Ratings

The impact of totally clearing 90-100% of a rating area is the same, it is the highest impact because the unit is removed and what remains requires a very intensive management program. The amount of area cleared of a given area has less impact in a high capability rating than the same area in a less capability rating for areas below this total 90-100% claring action. This reinforces the criteria utilized to determine the first level ratings for vegetation related to successional stage.

f) Highest Impact Based on a Threshold Level Related to the Environmental Action Considered

This relationship exists in the scoring of compaction density to vegetation. The scoring rationale is based on the ability of the vegetation type to re-succeed. The first plants to re-establish are the least sensitive and eaerliest in the successional progression. The highest impact therefore is experienced on 90-100% compaction density for the level 3 rating and correspondingly at 20-30% compaction density for the most sensitive level 10 rating.

No Impact - the action in some cases does not affect the ratings in any way because the resource which the rating represents is not altered or removed. In other cases the resource is removed, but no impact is realized. The action of excavation removes the resource but assumes that the same material with the same rating exists at the bottom of the excavation and the same profile exists on the edges of the excavation. The action of removing the topsoil by stripping removed the resource, therefore no management for the topsoil trafficability or erodibility is required, the impact on the agricultural rating however is negative.

In some cases the action does not have an impact because the action has been preceeded by a negative impacting action, for instance stripping does not impact vegetation becuase stripping is preceeded by clearing which impacts vegetation negatively.

No impact has been scored for replacement in excavation of impervious and pervious materials on profile trafficability and compressibility because the action does not qualify specifically the characteristics of the material being replaced except as related to permeability.

Positive Impact - the impact of some actions on the ratings can be positive, an improvement in the characteristics relative to the type of rating. This occurs in several ways, either by introducing an imported material as is the case of replacing a pervious material in an impermeable area, and covering an area with asphalt which is highly trafficable and nonerodible; or by completing an action which improves the condition of the existing resource and would in fact improve the rating as is the case in when the density of the sol is increased by compaction the erodibility is decreased, because the soil is more cohesive.

4.2.2.3 N-3 Matrix - Site Selection

The N-3 matrix is a site selection matrix where the vertical x-axis down the left side indicating the natural factors as first level rating categories have been scored for their implications to implementing the environmental actions listed across the horizontal y-axis.

The score ranging from 0 to 10 represent the site selection limitations of the natural factors to undertake each environmental action. The higher the score the greater the limitation.

The N-3 matrix scoring was developed by the study team and reviewed by the committee. In spaces where no score is indicated means no limitation exists. The question asked of the specialist in scoring this matrix is the following. "Given a first level rating of a neutral factor, what is the relative difficulty which one would face in attempting to perform or achieve a certain environmental action?

An example from the N-3 matrix will serve to explain the logic. The least trafficable topsoil (natural factor: topsoil trafficability; unit: 9) will be the most difficult to strip for the purpose of developing an area. The greater the area one may wish to strip (from 10% to 100%), the more difficult the action becomes. Therefore an environmental action of 100% stripping is rated with a relative difficulty of 10.

The site selection scoring system has three possibilities:

1. Firstly, the scoring reinforces the first level rating intent where the least capable first level rating has the greatest limitations, and the intensity of the environmental action is directly proportional to the scoring, except in three situations where the intensity of the action is not the consideration. It is the amount of action and the actual construction that is limited by the rating, this is the case for topsoil trafficability for compaction area, profile trafficability for compaction area, and 0-1 M water table level(s) for compaction density.

2. Secondly, the inverse of the first follows, the scoring in three situations in opposite, so that the shallowest slopes have the most limitation in accelerating drainage and the most permeable profiles have the most limitations for permanent impoundment and chemical change where no percolation is desirable.

3. Thirdly, the scoring is not a linear progression function as are the first two possibilities, but is a curved function in the case of vegetation tolerance to clearing where a peak total exists in the middle first level ratings, and an irregular

progression for vegetation to irrigation, and more immediate peaking for vegetation to septic tile field and seeding/landscaping actions.

An example of the scoring rationale for the N-3 matrix is outlined thus:

Natural Factors Category	Environmental Action	Scoring Rationale
Slope	Excavation +1M	- steeper slopes most limiting for moving equipment, excavation to depths requires larger equipment, cut and filles more difficult.
	0-1M	- only shallow depth not as difficult.
	Surface Coverage	- difficulty in drainage design and run-off rates, equipment limitation in steeper slopes.
	Compact. Density	- no mechanical, no clearing necessary therefore no limitation by slope per se, limitations of erodibility - separate category.
	Compact. Area	- mechanical compaction to optimum density limitations incrase with slope steepness.
	Stripping Area	- mechanical operation limitations increased with slope steepness
	Clearing Area	- mechanical operation limitations increase with slope steepness.
	Perm. Impoundm't	- limitations increase with slope steepness.
	Irrigation	- limitations increase with slope steepness.
	Drainage Accelat'n	- limitations increase with slope steepness.
	Control'd Drainage	- limitations increase with slope steepness.

Natural Factors Category	Environmental Action	Scoring Rationale
	Seeding Landscaping	- limitations increase with slope steepness.
	Thinning	- limitation increase with steepness, not as severe as clearing.
	Planting	- limitation increase with steepness, not as severe as seeding.
	Structures	- limitations increase with steepness.

4.2.2.4 Capability Mapping

The elements in the matrix system are added to produce aggregate totals for N-4, N-5 and N-6. These aggregates can then be broken down into categories or bands representing twenty percent of the total range. This can be done for each of the 107 land uses or for representative uses.

Twenty-five representative land uses were selected on the basis of the N-4, N-5 and N-6 aggregate scores to represent the continuum of development intensity within seven land use categories. These twenty-five uses were later reduced to seven representative uses as is explained in subsequent sections. An example of the computerized product of the Matrix system, indicating the aggregate scores for Land Uses #5 (4ha individual serviced) #11 (1000m^2 residential serviced) and #95 (resort accommodation) is reproduced on the pages following.

```
                       USE NUMBER   5     RES 1UNIT/.4H-INDIVID (1A)

                       .....................................................................................
                       CODE     N4     CLASS      N5     CLASS      N6     CLASS            NOTES
                       .....................................................................................
                        0.      0.50    1.00      7.90    1.00      8.40    1.00
                        1.      1.00    1.00     15.80    1.00     16.80    1.00
                        2.      1.50    1.00     23.70    2.00     25.20    2.00
                        3.      2.00    1.00     31.60    2.00     33.60    2.00
SLOPE                   4.      2.50    1.00     39.50    3.00     42.00    3.00
                        5.      3.00    1.00     47.40    3.00     50.40    3.00
                        6.      3.50    1.00     55.30    4.00     58.80    4.00
                        7.      4.00    1.00     63.20    4.00     67.20    4.00
                        8.      4.50    1.00     71.10    5.00     75.60    5.00
                        9.      5.00    1.00     79.00    5.00     84.00    5.00
                       .....................................................................................
                        0.      0.0     0.0       3.30    1.00      3.30    1.00
                        1.      0.0     0.0       7.04    1.00      7.04    1.00
                        2.      0.0     0.0      10.79    1.00     10.79    1.00
                        3.      0.0     0.0      14.53    1.00     14.53    1.00
TOPSOIL TRAFF.          4.      0.0     0.0      18.28    2.00     18.28    2.00
                        5.      0.0     0.0      22.02    2.00     22.02    2.00
                        6.      0.0     0.0      25.77    2.00     25.77    2.00
                        7.      0.0     0.0      29.51    2.00     29.51    2.00
                        8.      0.0     0.0      33.26    3.00     33.26    2.00
                        9.      0.0     0.0      37.00    3.00     37.00    3.00
                       .....................................................................................
                        0.      3.10    1.00      3.65    1.00      6.75    1.00
                        1.      6.20    1.00      7.30    1.00     13.50    1.00
                        2.      9.30    2.00     10.95    1.00     20.25    2.00
                        3.     12.40    2.00     14.60    1.00     27.00    2.00
ERODIBILITY             4.     15.50    3.00     18.25    2.00     33.75    2.00
                        5.     18.60    3.00     21.90    2.00     40.50    3.00
                        6.     21.70    4.00     25.55    2.00     47.25    3.00
                        7.     24.80    4.00     29.20    2.00     54.00    4.00
                        8.     25.90    5.00     32.85    3.00     58.75    4.00
                        9.     31.00    5.00     36.50    3.00     67.50    4.00
                       .....................................................................................
                        0.     10.00    2.00      2.00    1.00     12.00    1.00
                        1.      9.60    2.00      4.00    1.00     13.60    1.00
                        2.      9.20    2.00      6.00    1.00     15.20    1.00
                        3.      8.80    2.00      8.00    1.00     16.80    1.00
AGRIC. RATING           4.      8.40    2.00     10.00    1.00     18.40    2.00
                        5.      8.00    2.00     12.00    1.00     20.00    2.00
                        6.      7.60    2.00     14.00    1.00     21.60    2.00
                        7.      7.20    2.00     16.00    1.00     23.20    2.00
                        8.      6.80    2.00     18.00    2.00     24.80    2.00
                        9.      6.40    1.00     20.00    2.00     26.40    2.00
                       .....................................................................................
                        0.      3.00    1.00      1.00    1.00      4.00    1.00
                        1.      5.45    1.00      2.00    1.00      7.45    1.00
                        2.      7.90    2.00      3.00    1.00     10.90    1.00
                        3.     10.35    2.00      4.00    1.00     14.35    1.00
PROFILE PERM.           4.     12.80    3.00      5.00    1.00     17.80    1.00
                        5.     13.50    3.00      6.00    1.00     19.50    2.00
                        6.     11.50    2.00      7.00    1.00     18.50    2.00
                        7.      9.50    2.00      8.00    1.00     17.50    1.00
                        8.      7.50    2.00      9.00    1.00     16.50    1.00
                        9.      5.50    1.00     10.00    1.00     15.50    1.00
                       .....................................................................................
                        0.      0.0     0.0       3.90    1.00      3.90    1.00
                        1.      0.0     0.0       8.58    1.00      8.58    1.00
                        2.      0.0     0.0      13.26    1.00     13.26    1.00
                        3.      0.0     0.0      17.93    2.00     17.93    1.00
PROFILE TRAFF.          4.      0.0     0.0      22.61    2.00     22.61    2.00
                        5.      0.0     0.0      27.29    2.00     27.29    2.00
                        6.      0.0     0.0      31.97    2.00     31.97    2.00
                        7.      0.0     0.0      36.64    3.00     36.64    3.00
                        8.      0.0     0.0      41.32    3.00     41.32    3.00
                        9.      0.0     0.0      46.00    3.00     46.00    3.00
                       .....................................................................................
                        0.      0.0     0.0       1.60    1.00      1.60    1.00
                        1.      0.0     0.0       3.98    1.00      3.98    1.00
                        2.      0.0     0.0       6.36    1.00      6.36    1.00
                        3.      0.0     0.0       8.73    1.00      8.73    1.00
COMPRESSIBILITY         4.      0.0     0.0      11.11    1.00     11.11    1.00
                        5.      0.0     0.0      13.49    1.00     13.49    1.00
                        6.      0.0     0.0      15.87    1.00     15.87    1.00
                        7.      0.0     0.0      18.24    2.00     18.24    1.00
                        8.      0.0     0.0      20.62    2.00     20.62    2.00
                        9.      0.0     0.0      23.00    2.00     23.00    2.00
                       .....................................................................................
                        0.      2.50    1.00      0.0     0.0       2.50    1.00
                        1.      0.0     0.0       0.0     0.0       0.0     0.0
                        2.      0.0     0.0       0.0     0.0       0.0     0.0
                        3.      0.0     0.0       0.0     0.0       0.0     0.0
WATER TABLE-SEEP        4.      0.0     0.0       0.0     0.0       0.0     0.0




                        5.      0.0     0.0       0.0     0.0       0.0     0.0
                        6.      5.00    1.00     24.75    2.00     29.75    2.00
                        7.      0.0     0.0      53.50    4.00     53.50    4.00
                        8.     10.00    2.00     78.50    5.00     68.50    5.00
                        9.      0.0     0.0     150.00    0.0     150.00    0.0             61.50
                       .....................................................................................
                        0.      0.70    1.00      0.0     0.0       0.70    1.00
                        1.      4.40    1.00      8.00    1.00     12.40    1.00
                        2.      6.10    1.00     19.00    2.00     25.10    2.00
                        3.      7.80    2.00     31.00    2.00     39.80    3.00
VEG. TOLERANCE          4.      9.50    2.00     38.00    3.00     47.50    3.00
                        5.     11.20    2.00     41.00    3.00     52.20    3.00
                        6.     12.90    3.00     43.40    3.00     56.30    4.00
                        7.     14.60    3.00     45.80    3.00     60.40    4.00
                        8.     16.30    3.00     48.20    4.00     64.50    4.00
                        9.     17.00    3.00     50.60    4.00     67.60    4.00
```

```
                 USE NUMBER  11     FES 1UNIT/1000SQM-PIPED BOTH

                 .........................................................................................
                 CODE    N4     CLASS      N5     CLASS      N6     CLASS             NOTES
                 .........................................................................................
                 0.      0.50    1.00     10.10    1.00     10.60    1.00
                 1.      1.00    1.00     20.20    1.00     21.20    1.00
                 2.      1.50    1.00     30.30    2.00     31.80    2.00
                 3.      2.00    1.00     40.40    2.00     42.40    2.00
SLOPE            4.      2.50    1.00     50.50    3.00     53.00    3.00
                 5.      3.00    1.00     60.60    3.00     63.60    3.00
                 6.      3.50    1.00     70.70    4.00     74.20    4.00
                 7.      4.00    1.00     80.80    4.00     84.80    4.00
                 8.      4.50    1.00     90.90    5.00     95.40    5.00
                 9.      5.00    1.00    101.00    5.00    106.00    5.00
                 .........................................................................................
                 0.     10.00    3.00      4.00    1.00     14.00    1.00
                 1.      9.00    2.00      8.11    1.00     17.11    1.00
                 2.      8.00    2.00     12.22    1.00     20.22    1.00
                 3.      7.00    2.00     16.33    1.00     23.33    2.00
TOPSOIL TRAFF.   4.      6.00    2.00     20.44    1.00     26.44    2.00
                 5.      5.00    1.00     24.56    2.00     29.56    2.00
                 6.      4.00    1.00     28.67    2.00     32.67    2.00
                 7.      3.00    1.00     32.78    2.00     35.78    2.00
                 8.      2.00    1.00     36.89    2.00     38.89    2.00
                 9.      1.00    1.00     41.00    2.00     42.00    2.00
                 .........................................................................................
                 0.      2.40    1.00      2.85    1.00      5.25    1.00
                 1.      4.80    1.00      5.70    1.00     10.50    1.00
                 2.      7.20    2.00      8.55    1.00     15.75    1.00
                 3.      9.60    2.00     11.40    1.00     21.00    1.00
ERODIBILITY      4.     12.00    3.00     14.25    1.00     26.25    2.00
                 5.     14.40    3.00     17.10    1.00     31.50    2.00
                 6.     16.80    4.00     19.95    1.00     36.75    2.00
                 7.     19.20    4.00     22.80    2.00     42.00    2.00
                 8.     20.60    5.00     25.65    2.00     46.25    3.00
                 9.     24.00    5.00     26.50    2.00     52.50    3.00
                 .........................................................................................
                 0.     21.00    5.00      2.00    1.00     23.00    2.00
                 1.     19.60    5.00      4.00    1.00     23.60    2.00
                 2.     18.20    4.00      6.00    1.00     24.20    2.00
                 3.     16.80    4.00      8.00    1.00     24.80    2.00
AGRIC. RATING    4.     15.40    4.00     10.00    1.00     25.40    2.00
                 5.     14.00    3.00     12.00    1.00     26.00    2.00
                 6.     13.60    3.00     14.00    1.00     27.60    2.00
                 7.     13.20    3.00     16.00    1.00     29.20    2.00
                 8.     12.80    3.00     18.00    1.00     30.80    2.00
                 9.     12.40    3.00     20.00    1.00     32.40    2.00
                 .........................................................................................
                 0.     16.00    4.00     10.00    1.00     26.00    2.00
                 1.     16.65    4.00      9.00    1.00     25.65    2.00
                 2.     17.30    4.00      8.00    1.00     25.30    2.00
                 3.     17.95    4.00      7.00    1.00     24.95    2.00
PROFILE PERM.    4.     18.60    4.00      6.00    1.00     24.60    2.00
                 5.     17.00    4.00      5.00    1.00     22.00    1.00
                 6.     14.50    3.00      4.00    1.00     18.50    1.00
                 7.     12.00    3.00      3.00    1.00     15.00    1.00
                 8.      9.50    2.00      2.00    1.00     11.50    1.00
                 9.      7.00    2.00      1.00    1.00      8.00    1.00
                 .........................................................................................
                 0.      0.0     0.0       4.80    1.00      4.80    1.00
                 1.      0.0     0.0      10.16    1.00     10.16    1.00
                 2.      0.0     0.0      15.51    1.00     15.51    1.00
                 3.      0.0     0.0      20.87    1.00     20.87    1.00
PROFILE TRAFF.   4.      0.0     0.0      26.22    2.00     26.22    2.00
                 5.      0.0     0.0      31.58    2.00     31.58    2.00
                 6.      0.0     0.0      36.93    2.00     36.93    2.00
                 7.      0.0     0.0      42.28    3.00     42.28    2.00
                 8.      0.0     0.0      47.64    3.00     47.64    3.00
                 9.      0.0     0.0      53.00    3.00     53.00    3.00
                 .........................................................................................
                 0.      0.0     0.0       4.10    1.00      4.10    1.00
                 1.      0.0     0.0       8.76    1.00      8.76    1.00
                 2.      0.0     0.0      13.41    1.00     13.41    1.00
                 3.      0.0     0.0      18.07    1.00     18.07    1.00
COMPRESSIBILITY  4.      0.0     0.0      22.72    2.00     22.72    2.00
                 5.      0.0     0.0      27.38    2.00     27.38    2.00
                 6.      0.0     0.0      32.03    2.00     32.03    2.00
                 7.      0.0     0.0      36.68    2.00     36.68    2.00
                 8.      0.0     0.0      41.34    3.00     41.34    2.00
                 9.      0.0     0.0      46.00    3.00     46.00    3.00
                 .........................................................................................
                 0.     10.00    3.00      2.50    1.00     12.50    1.00
                 1.      0.0     0.0       0.0     0.0       0.0     0.0
                 2.      0.0     0.0       0.0     0.0       0.0     0.0
                 3.      0.0     0.0       0.0     0.0       0.0     0.0
WATER TABLE-SEEP 4.      0.0     0.0       0.0     0.0       0.0     0.0




                 5.      0.0     0.0       0.0     0.0       0.0     0.0
                 6.      7.50    2.00     33.25    2.00     40.75    2.00
                 7.      2.50    1.00     65.75    4.00     68.25    4.00
                 8.      5.00    1.00     93.25    5.00     98.25    5.00
                 9.      0.0     0.0     140.00    0.0     140.00    0.0               34.00
                 .........................................................................................
                 0.      1.00    1.00      0.0     0.0       1.00    1.00
                 1.      5.00    1.00      7.75    1.00     12.75    1.00
                 2.      7.00    2.00     15.50    1.00     22.50    2.00
                 3.      9.00    2.00     23.25    2.00     32.25    2.00
VEG. TOLERANCE   4.     11.00    3.00     31.00    2.00     42.00    2.00
                 5.     13.00    3.00     34.00    2.00     47.00    3.00
                 6.     15.00    4.00     35.10    2.00     51.10    3.00
                 7.     17.00    4.00     38.20    2.00     55.20    3.00
                 8.     19.00    4.00     40.30    2.00     59.30    3.00
                 9.     20.00    5.00     42.40    3.00     62.40    3.00
```

```
                          USE NUMBER  95     REC RESORT/ACCOM

                          CODE     N4    CLASS      N5    CLASS      N6    CLASS          NOTES
                          0.     0.50    1.00     9.70    1.00    10.20    1.00
                          1.     1.00    1.00    19.40    1.00    20.40    1.00
                          2.     1.50    1.00    29.10    2.00    30.60    2.00
                          3.     2.00    1.00    38.80    2.00    40.80    2.00
SLOPE                     4.     2.50    1.00    48.50    3.00    51.00    3.00
                          5.     3.00    1.00    58.20    3.00    61.20    3.00
                          6.     3.50    1.00    67.90    4.00    71.40    4.00
                          7.     4.00    1.00    77.60    4.00    81.60    4.00
                          8.     4.50    1.00    87.30    5.00    91.80    5.00
                          9.     5.00    1.00    97.00    5.00   102.00    5.00

                          0.    10.00    3.00     4.80    1.00    14.80    1.00
                          1.     9.00    2.00     9.71    1.00    18.71    1.00
                          2.     8.00    2.00    14.62    1.00    22.62    2.00
                          3.     7.00    2.00    19.53    1.00    26.53    2.00
TOPSOIL TRAFF.            4.     6.00    2.00    24.44    2.00    30.44    2.00
                          5.     6.00    2.00    29.36    2.00    35.36    2.00
                          6.     6.00    2.00    34.27    2.00    40.27    2.00
                          7.     6.00    2.00    39.18    2.00    45.18    3.00
                          8.     6.00    2.00    44.09    3.00    50.09    3.00
                          9.     4.00    1.00    49.00    3.00    53.00    3.00

                          0.     1.90    1.00     2.90    1.00     4.80    1.00
                          1.     3.80    1.00     5.80    1.00     9.60    1.00
                          2.     5.70    2.00     8.70    1.00    14.40    1.00
                          3.     7.60    2.00    11.60    1.00    19.20    1.00
ERODIBILITY               4.     9.50    2.00    14.50    1.00    24.00    2.00
                          5.    11.40    3.00    17.40    1.00    28.80    2.00
                          6.    13.30    3.00    20.30    2.00    33.60    2.00
                          7.    15.20    4.00    23.20    2.00    38.40    2.00
                          8.    16.10    4.00    26.10    2.00    42.20    3.00
                          9.    19.00    5.00    29.00    2.00    48.00    3.00

                          0.    23.00    5.00     2.00    1.00    25.00    2.00
                          1.    21.40    5.00     4.00    1.00    25.40    2.00
                          2.    19.80    5.00     6.00    1.00    25.80    2.00
                          3.    18.20    4.00     8.00    1.00    26.20    2.00
AGRIC. RATING             4.    16.60    4.00    10.00    1.00    26.60    2.00
                          5.    15.00    4.00    12.00    1.00    27.00    2.00
                          6.    14.40    4.00    14.00    1.00    28.40    2.00
                          7.    13.80    3.00    16.00    1.00    29.80    2.00
                          8.    13.20    3.00    18.00    1.00    31.20    2.00
                          9.    12.60    3.00    20.00    1.00    32.60    2.00

                          0.     5.00    1.00     1.00    1.00     6.00    1.00
                          1.     7.00    2.00     2.00    1.00     9.00    1.00
                          2.     9.00    2.00     3.00    1.00    12.00    1.00
                          3.    11.00    3.00     4.00    1.00    15.00    1.00
PROFILE PERM.             4.    13.00    3.00     5.00    1.00    18.00    1.00
                          5.    12.50    3.00     6.00    1.00    18.50    1.00
                          6.    11.00    3.00     7.00    1.00    18.00    1.00
                          7.     9.50    2.00     8.00    1.00    17.50    1.00
                          8.     8.00    2.00     9.00    1.00    17.00    1.00
                          9.     6.50    2.00    10.00    1.00    16.50    1.00

                          0.     0.0     0.0      4.70    1.00     4.70    1.00
                          1.     0.0     0.0     10.06    1.00    10.06    1.00
                          2.     0.0     0.0     15.43    1.00    15.43    1.00
                          3.     0.0     0.0     20.60    2.00    20.80    1.00
PROFILE TRAFF.            4.     0.0     0.0     26.17    2.00    26.17    2.00
                          5.     1.00    1.00    31.53    2.00    32.53    2.00
                          6.     2.00    1.00    36.90    2.00    38.90    2.00
                          7.     3.00    1.00    42.27    3.00    45.27    3.00
                          8.     4.00    1.00    47.63    3.00    51.63    3.00
                          9.     3.00    1.00    53.00    3.00    56.00    3.00

                          0.     0.0     0.0      3.90    1.00     3.90    1.00
                          1.     0.0     0.0      8.46    1.00     8.46    1.00
                          2.     0.0     0.0     13.03    1.00    13.03    1.00
                          3.     0.0     0.0     17.60    1.00    17.60    1.00
COMPRESSIBILITY           4.     0.0     0.0     22.17    2.00    22.17    2.00
                          5.     0.0     0.0     26.73    2.00    26.73    2.00
                          6.     0.0     0.0     31.30    2.00    31.30    2.00
                          7.     0.0     0.0     35.87    2.00    35.87    2.00
                          8.     0.0     0.0     40.43    3.00    40.43    2.00
                          9.     0.0     0.0     45.00    3.00    45.00    3.00

                          0.     0.0     0.0      2.50    1.00     2.50    1.00
                          1.     0.0     0.0      0.0     0.0      0.0     0.0
                          2.     0.0     0.0      0.0     0.0      0.0     0.0
                          3.     0.0     0.0      0.0     0.0      0.0     0.0
WATER TABLE-SEEP          4.     0.0     0.0      0.0     0.0      0.0     0.0




                          5.     0.0     0.0      0.0     0.0      0.0     0.0
                          6.     5.00    1.00    32.00    2.00    37.00    2.00
                          7.     2.50    1.00    64.25    4.00    66.75    4.00
                          8.     7.50    2.00    91.25    5.00    98.75    5.00
                          9.     0.0     0.0    140.00    0.0    140.00    0.0           38.00

                          0.     1.00    1.00     0.0     0.0      1.00    1.00
                          1.     7.00    2.00     7.75    1.00    14.75    1.00
                          2.     9.00    2.00    15.50    1.00    24.50    2.00
                          3.    11.00    3.00    24.25    2.00    35.25    2.00
VEG. TOLERANCE            4.    13.00    3.00    33.00    2.00    46.00    3.00
                          5.    15.00    4.00    35.00    2.00    50.00    3.00
                          6.    17.00    4.00    37.10    2.00    54.10    3.00
                          7.    18.00    4.00    39.20    2.00    57.20    3.00
                          8.    19.00    5.00    41.30    3.00    60.30    3.00
                          9.    20.00    5.00    43.40    3.00    63.40    4.00
```

4.2.3 Suitability Analysis

4.2.3.1 Suitability Matrix

The components of the suitability matrix are the cultural factors as identified in the inventory portion of thes study, and the range of land uses created by the study team to represent a complete range or potential impact intensities for analysis. Cultural factors from the columns of the suitability matrix, while land uses form the rows.

In this section the relationships and planning guidelines relative to the suitability of lcoating a land use proximate to a given cultural factor are scored. The cultural factors have been disaggregated into four or five setback distances for the purpose of analysis.

Setback distances from the Urban Centre cultural factor has been disaggregated into 0-800m, 800-1,600m, 1-5km, 5km+. The cultural factors Road Major, Roads Arterial, and Intensive Agricultural Operation have been broken into 0-100m, 100-400m, 400-800, and 800m+. All other cultural factors have been divded into 0-100m, 100-200m, 200-800m and 800m+.

The disaggregation of setback distances in this manner creates a logical series of "threshold distances" beyond which the situation ability of a particular use increases and the mitigative measures which may otherwise be required are reduced.

The matrix system uses a diagonal slash to indicate "not suitable", a dot to indicate "less suitable" and leaves the cell blank if the particular use is considered suitable in relation to the cultural factor.

The planning rationale used in the suitability matrix is mapped by computer in a series of setback bands from the cultural factors identified. The study team uses this information not as a set of hard and fast rules, but rather as a set of planning guidelines to adjust the location of the various land uses being considered for the study area. It was necessary, however, to map the suitability relationships in composite form. The cultural factors therfore had to be ranked in order to have the computer select by priority the setback distances relevant to each land use category.

4.2.3.2 Suitability Criteria

Twenty-five land uses representing seven generalized land use categories were selected on the basis of the range of capability scores from the N-6 matrix.

For each of the seven land use categories a table recording setback distances from cultural factors and the land uses specified from the suitability matrix was prepared. Within each land use category these setbacks were then scored in rank order of importance using a scale of 1-10.

The proximity in meters taken from the suitability matrix was broken down into "not suitable" and "mitigative", the latter category referring to the 'less suitable' scoring on the suitability matrix.

The ranking of suitability relative to the specific setback distance followed logic which, of necessity, varied somewhat between land use categories. However, in general terms, setbacks applied in recognition of a safety issue were ranked highest or most imporrant. Setbacks applied in conformity with existing legislation were generally ranked second in importance. Judgement, however, was applied in some cases, particularly where legislation in the form of Regulations could be waived by an appropriate administrative tribunalor quasi-judicial body appointed as a hearing authority.

Setbacks recommended due to noise, odour or dust pollution associated with the cultural factor in question generally ranked third in order of importance, while aesthetic reasoning figures highly in the remainder of the factors.

The questions of compatability of cultural factors with the land uses being assessed is reflected in the rank ordering within each land use category. For example, a setback of 0-800m for higher density serviced residential uses from a nature preserve, ranked as being less important than a setback of 200m between 1 acre parcels and the natura preserve. In this ranking decision, one had to consider both the distance variable and the density variable in assigning the rank.

An example of the suitability tables used in the development of suitability composites are reproduced in the pages following.

4.2.4 Capability/Suitability Composite Maps

Capability and suitability maps were prepared for the 25 representative land uses selected. The representation of capability was arranged in classes from 1 to 5 where a 1 represents the most capable land for that land use category. Suitability occured in 10 classes where a 10 represented the least suitable land for that particular land use category, disaggregated from the suitability composite for each category such as the Residential Serviced composite.

In order to combine capability and suitability to produce composite maps by computer, a matrix was prepared to combine the possible scores into a single continuum of capability/suitability classes from 1 to 5. This matrix is reproduced below:

SUITABILITY COMPOSITES - SCORING

1. RESIDENTIAL SERVICED	USES	PROXIMITY IN METRES			
CULTURAL FACTORS	(14, 12, 11, 10, 7)	NOT SUITABLE	SCORE	MITIGATIVE	SCORE
RAIL	14, 12, 11, 10, 7	0 - 200	10	200-800	3
MAJOR ROADS	14, 12, 11, 10, 7	0 - 800	5		
MAJOR TRANSMISSION PIPELINE	14, 12, 11, 10, 7	0 - 100	10		
URBAN CENTRE	14, 12, 11, 10			800-5000	1
	7	0 - 1600	7	1600-5000	2
ROADS ARTERIAL	14	N/A			
	12, 11, 10, 7	0 - 100	4		
SEWER	14, 12, 11, 10, 7			200+	3
WATER	14, 12, 11, 10, 7			200+	3
MINOR ROADS					
WABAMUN LAKE	14, 12, 11	0 - 200	8		
	10, 7	0 - 100	9		
MINOR LAKE	14, 12, 11, 10, 7	0 - 100	5		
NATURE PRESERVE	14, 12, 11, 10	0 - 800	6		
	7	0 - 200	7		
PROVINCIAL PARK	14, 12, 11, 10, 7	0 - 800	5		
NORTH SASKATCHEWAN RIVER	14, 12, 11, 10	0 - 200	6	(Highvale	
	7	0 - 100	7	Only)	
MINOR RIVER	14, 12, 11, 10, 7	0 - 100	5	(Highvale Only)	
INTENSIVE AGRICULTURAL	14, 12, 11, 10, 7	0 - 400	10		
CR/RESORT		N/A			
GENERATION PLANT	14, 12, 11, 10, 7	0 - 800	5		
MAJOR POWER TRANSMISSION	14, 12, 11, 10, 7	0 - 100	5		

USES: No. 7 - .4 ha (1 ac) both services)
10 - 2000 m^2 both services
11 - 1000 m^2 both services
12 - 500 m^2 both services
14 - 25+ units/ha both services

CAPABILITY/SUITABILITY COMPOSITE MATRIX

Capability Class	Suitability Class										
	0	1	2	3	4	5	6	7	8	9	10
1	1	2	2	2	2	2	2	2	3	3	3
2	2	2	2	2	3	3	3	3	4	4	4
3	3	3	3	3	4	4	4	4	5	5	5
4	4	4	4	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
0	5	5	5	5	5	5	5	5	5	5	5

The capability/suitability composite matrix reflects in its scoring the fact that mitigative measures can often render land suitable for a certain land use. However, if the natural resource exhibits low capability, mitigative measures are either much more expensive or are less feasible.

In the above matrix where a low capability, for example Class 5 occurs, the suitability of the land is irrelevant. The combined map will score the area as Class 5. Where capability is good as in the Class 2 areas, the combined map will show a range of scores from 2 to 4 depending upon the suitability of the land.

Capability/Suitability Composite maps were prepared in this manner, representing each of the twenty-five land uses selected as reprsentative uses earlier. The function of the computer, essentially, is to overlay the relevant suitability map on the capability map and combine the two maps into a single composite by applying the rules established in the matrix.

4.2.5 Selection of Represenative Uses

The composite maps were reviewed both mechanically and visually in order to determine whether selection of single uses to represent a land use category was feasible.

The intitial step involved comparison of the frequency (in pixel numbers) of the occurrence of capable and suitable use areas for each of the land uses within a land use category. The patterns were compared with the individual capability maps and suitability maps in order to determine the extent of overlay between uses. During this exercise a number of land uses were removed from further analysis because of their uniqueness from a locational viewpoint or because they can generally be associated with other uses.

The following uses were selected as being representative for each category:

Land Use Category	Selected Land Use	Use Number
Residential Services	1,000 m_2 both services	11
Residential Unservces	.4 ha (1 ac) individual	5
Business Industrial	Professional/Business Park	20
Agriculture	Annual Crops	42
Resort Recration	Resort Accommodation	95
Recreation Day Use	Primitive Camping	82
Infrastructure	Paved 4-lane	53

4.2.6 Land Use Models

The land use categories were combined in a manner which would indicate the areas which are most suitable and capable of sustaining a variety of uses.

Two land use models representing five of the seven land use categories were developed from the respective capability/suitability maps. Areas of capability/suitability Classes 1, 2 and 3 were withdrawn, combined with Classes 1, 2, 3 capability/suitability for other uses, re-coded and mapped by computer. The computer mapping identifies areas which have been scored as being suitable and capable for all combinations of the uses being considered.

The Residential/Resort Model is described as an example:

All residential uses were combined in order to indicate areas were which best for resort development, for served residential development, and/or for unserviced residential land use. The table below indicates the breakdown and re-scoring of the composite maps to produce the model.

Residential/Resort Model

Use Number	Score	Tone Combinations	Assigned Tone
11	1, 2, 3		1
5	1, 2, 3		2
95	1, 2, 3		3
11 5	1, 2, 3 1, 2, 3	1 2	4
11 95	1, 2, 3 1, 2, 3	1 3	5
5 95	1, 2, 3 1, 2, 3	2 3	6
11 5 95	1, 2, 3 1, 2, 3 1, 2, 3	1 2 3	7

The seven assigned tones indicate the permutations and combinations of lands which demonstrated high capability (1, 2, 3) for the three land use categories being considered. Areas which scored 4 and 5 for all of these lands uses are shown as blank (or white) aras on the grid mode computer map.

A capability composite map was prepared using the same re-scoring method so that comparison eliminating suitability factors could be achieved. Comparison could also be achieved between the composite map and capability or suitability maps for individual uses.

4.2.7 Post-Mine Capability Analysis

The post-mine capability analysis process commenced with an evaluation of capability generation for selected uses comparison of the computer printouts. These included:

1) slope and spoil ratings of erodibility, agricultural rating, profile permeability, profile trafficability, profile compressibility,

2) same as 1) above, but added water table rating 0 in post mining area, vegetation tolerance rating 1 in post ming area,

3) same as 2) above, but added topsoil trafficability rating 3 in post mine area.

The three sets were compared and discrepancies in the areas outside of the mine from the pre-mine capability analysis were assessed. By utilizing the third combination the outside areas were identical in the pre and post mine printouts. However, the topsoil trafficability upwardly biased the mine area by assuming the first level rating the equivalent of the best situation in the pre-mine soils. This was inaccurate.

The evaluation of relative capability scores for three combinations was benchmarked against a thorough knowledge of specific land units, such as the northwest corner, the upland south of the highway at the west end and the slope areas in the south-central portion of the study area. These "benchmark" locations were important to assess the capability combinations.

The first combination did not yeld sufficient co-relation with the pre-mine because the water table tends to be the major constraining site selection factor for most uses. By eliminating this factor in the analysis the "benchmark" locations in existing high water table areas were more highly classified.

The decision to continue to capability analysis with the second combination [all of 1 plus water table (0) and vegation tolerance (1)] includd the determination that the change in scoring range generated by cross tabulating through the matrix was not signficant. Although the range had a smaller upper limit (because the topsoil trafficability score was deleted), the ranges for assignment of the 1 to 5 classes in limited situation cause the pixel to be adjusted by only one class. In the post mine analysis, the relative capability in the mine area was generally higher (an overall improvement for most uses) and the capability/suitability analysis data in the final modelling should be upwardly biased to eliminate Class 3 scores which were been included in some of the modelling alternatives for the pre-mine situation. Threfore, the slight variation caused by eliminating topsoil trafficability overall (picnic full serviced) and #80 (offroad/snowmobile) where the topsoil trafficability and the trafficability without topsoil exists is a factor of importance. For these few uses all the combinations were generated for refrence and the variations, particularly in the mine area, were noted for the final modelling and subjective interpretation exercise in the preparation of the final post mine plan.

For these uses it was decided to utilize the trafficability first level rating overlay as a check of the final locations. This checking with the overlays was consistent with the agriculturally oriented uses.

5.0 PREDICTION AND RATING OF POST-MINING SURFACE CHARACTERISTICS

The purpose of this portion of the paper is to outline in detail the methodologies developed to predict and rate selected characteristics of the Whitewood post-mining surface. The systems developed are, at most, semi-quantitative, but represent a rigorous attempt to record all rationalizations and assumptions numerically, thus ensuring consistency throughout the excercise and clear documentation of each step involved.

This part of the paper contained excerpts from the Post-Mining First Level Ratings Study prepared for TransAlta Utilities but is not meant to replicate that report. It is intended to outline the methodologies used and demonstrate the value of a numerically based system for post-mine land use planning.

5.1 Introduction

A method was required by which to predict and rate the performance of the post-mining land surface in terms of trafficability, permeability, compressibility, erodibility, capability for arable agriculture and revegetation from which to derive measures of its capability. To achieve this end required an appreciation of the behaviour of the existing in-situ material from which to develop a model of the landscape as it would exist after mining. The characteristics of the present land surface most influencing its performance in terms of the factors mentioned above were considered to be soil texture, slope, porosity, stoniness and contrasting strata. These characteristics were evaluated for the various strata of the existing overburden. A model of the post-mine landscape was generated by projecting probable mining methods and sequences on the overburden geology to determine how strata would be rearranged after mining and which strata would constitute the post-mining surface. The post-mining surface was first delineated into units which consisted of similar stratagraphic rearrangement and classified on the basis of the factors.

The results of this exercise are both subjective and empirical as is any attempt to forecast the outcome of mining through variable materials where the rate and sequence of work is dictated by varying coal demands and spur-of-the-moment operator decisions. Nevertheless, the method applied represents the one realistic method of approximating the composition of the post-mine surface and predicting its behaviour the information presented here, despite its empiricism is, under the circumstances, a workable basis for planning.

5.2 Objectives

The objectives of the study were to:

1. Develop a methodology to predict the characteristics of the post-mining surace at Whitewood Mine;
2. Create a hypothetical map of the post-mining surface, showing performance characteristics that reflect its capability;
3. Develop a system for rating the post-mining surface in terms of capability, and
4. Calculate first level ratings for homogenous units of the post-mining surface.

5.3 Assumptions

The rating system was developed to predict spoil conditions at Whitewood Mine and cannot be applied to other environments with distinctly different spoils or climatic conditions. Spoil conditions were defined only for the immediate post-mining situation, i.e. just after recontouring. Some assumed attributes of this "young" spoil are described below:

- Bulk density is highly variable, both spatially and with depth, ranging within about 1.0 to 1.7 gm/cm^3. Thus, the material is neither very loose nor very dense.
- Void spaces and large pores occur, especially in association with stones and large coarse fragments. Development activities which involve traffic, compression, agriculture, etc., will have a greater impact on the bulk density, permeability, erodability of this young spoil than they would on a stable biogeophysical system.

- The organic matter content of surface spoil is very low unless selectively handled peat or topsoil is respread. Thus, water holding capacity, cation exchange capacity and structural development depend on characteristics of the physical fraction of the spoil.

- Development of the mine spoil for specific land uses will alter its characteristics. Spoil properties after development will be determined by land use and the associated management practices.

5.4 Definition of Terms

5.4.1 Soil

In this report, references to soil refer to newly recontoured spoil materials. Topsoil and subsoil refer to selectively handled salvage materials, removed prior to mining and respread over the recontoured spoil surface.

5.4.2 Trafficability

Trafficability is defined as the ability of a soil to support traffic without incurring an increase in bulk density beyond the limits for an intended land use (Paul and de Vries, 1979). It was assumed that changes in bulk density would occur most readily in material containing stones (15 to 50% by volume) due to packing of fine grain sized particles into the void spaces around many of the stones. Under dry conditions, clay and loam were considered more trafficable than sand or gravel textured materials. The trafficability of these materials was reversed under wet conditions.

5.4.3 Compressibility

Compressibility refers to the potential for volume change that a soil will undergo per unit increment in stress applied to the surface (Larson *et al.*, 1980). Since compressibility is independent of soil moisture content, only one set of ratings were calculated. It was assumed that stony and coarse textured materials are more resistant to an applied stress than fine textured and stone free spoil.

5.4.4 Permeability

Parr and Bertrand in Gray (1970) define permeability as "the quality or state of a porous medium relating to the readiness with which such a medium conducts or transmits fluids".

Two permeability scenarios were considered. In the first scenario, permeability "A", low permeability was regarded as low impact to provide ratings for situations in which impoundment of water will be required. Here, ratings increased under wet conditions since permeability is reduced as soil moisture content increases. For both wet and dry conditions, fine textured material with fine or few pores and several contrasting strata near the surface received the highest ratings indicating greatest impact or change.

For permeability "B", which defines conditions under which high permeability is viewed as low impact, the rankings of scenario one were reversed. In this case, coarse textured, porous material that is homogeneous to at least 5m was most highly rated. Ratings decreased for wet conditions.

5.4.5 Erodability

Erodability is the vulnerability or susceptability of a soil to erosion and reflect the expected rapidity and amount of soil loss by wind and/or water (Carson, 1971).

Under dry conditions, it was assumed that porous gravels on level slopes were least erodable and that loamy and sandy textured spoil on steep slopes was most susceptible to soil loss. When wet spoil conditions were assumed, criteria defining lowest impact did not change, but clay rather than sand was considered to be the most erodable material since the predominate sand sizes are medium to coarse in the spoil at Whitewood. Ratings for the criteria were lower under wet conditions since it was assumed that water erosion will increase with soil moisture.

5.4.6 Arable Farming Conditions

The pre-mine study provided ratings for agricultural capability. Since agriculture is a general term encompassing many types of management, agriculture has been more precisely defined as arable farming in which dryland cultivation is the basic management practice. Ratings have only been calcuated for dry conditions since it was assumed that cultivation would be avoided under wet conditions.

Loam and clay textured materials with moderate, but not excessive porosity, a relatively homogenous profile and few stones received highest ratings for arable farming. This type of spoil material will provide adequate conditions of drainage, cation exchange capacity, water holding capacity and ease of cultivation.

5.4.7 Revegetation Potential

Revegetation potential is defined as the ease with which vegetation will re-establish on the mine spoil through processes of natural succession. Spoil that provides both a satisfactory rooting medium and suitable microhabitats was rated most highly. Ratings reflect the same considerations as those for arable farming capability except that increasing stoniness and slope did not reduce potential to the same extent as was the case for the arable farming rating. Since topographic relief is necessary to produce habitat variability, slopes greater than 15% were not considered limiting unless erosion or permeability impacts were high.

5.5 Methodology

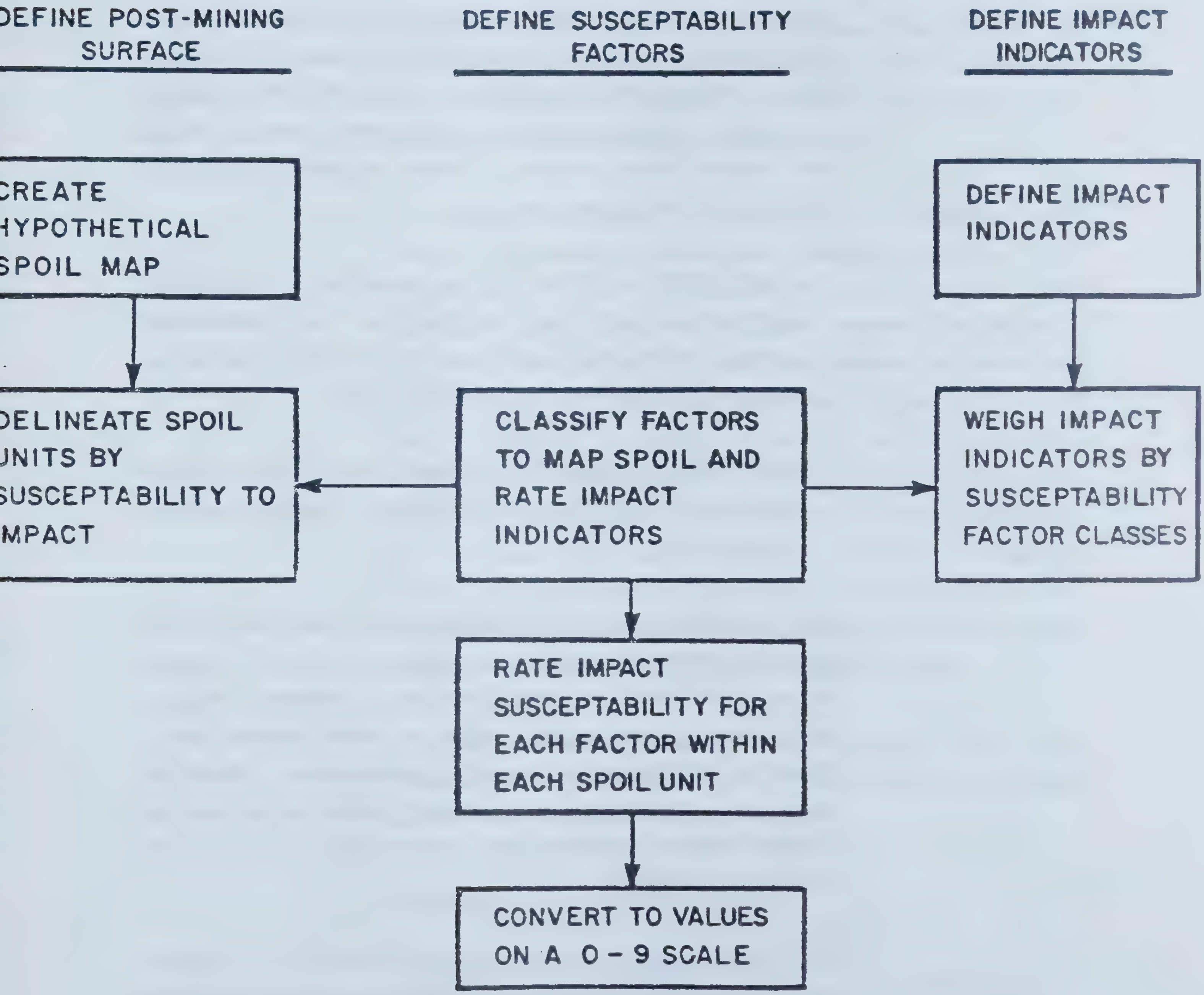
Several steps were involved in predicting the susceptability of the post-mining surface to impact from the natural factors - trafficability, compressibility, erodability, permeability, arable agriculture and revegetation. The process is outlined in the flow chart shown on the following page and is discussed in the following sections.

5.5.1 The Rating Concept

The first project requirement was development of a rating concept appropriate for evaluation of the post-mining surface at Whitewood Mine in terms of susceptability to impact. This required an understanding of the following:

- how each of the natural factors would affect a young spoil surface, what inherent properties of the spoil material would be affected and what magnitude of change could be expected; and,

ACTIVITY FLOW CHART


DEFINE POST-MINING SURFACE
DEFINE SUSCEPTABILITY FACTORS
DEFINE IMPACT INDICATORS
CREATE HYPOTHETICAL SPOIL MAP
DEFINE IMPACT INDICATORS
DELINEATE SPOIL UNITS BY SUSCEPTABILITY TO MPACT
CLASSIFY FACTORS TO MAP SPOIL AND RATE IMPACT INDICATORS
WEIGH IMPACT INDICATORS BY SUSCEPTABILITY FACTOR CLASSES
RATE IMPACT SUSCEPTABILITY FOR EACH FACTOR WITHIN EACH SPOIL UNIT
CONVERT TO VALUES ON A 0 – 9 SCALE

- the performance charactertistics of the post-mining environment, what properties could be used to map the recontoured spoil, and how these properties would be affected by the natural factors.

It became apparent that the most effective way of relating impact from the natural factors to changes in the spoil surface was to define both discrete spoil types and the natural factors by the same criteria, or impact indicators. Six impact indicators were selected - texture, slope, porosity, stoniness, profile depth and organic matter content. These criteria were chosen for the following reasons:

- they could be inferred from existing environmental information and extropolated to the post-mining surface with enough precision to provide a basis for distinction between spoil types; and,

- they were properties which would reflect the susceptibility of spoil units to impact from the natural factors.

The map legend on the following page shows how the six criteria were classified to define the spoil mapping units. The level of classification is general, because only broad distinctions could be made between spoil types on the basis of existing information. Each map unit was represented by a symbol (shown with the map legend) which describes map unit composition in terms of the six criteria.

The classification system was also used to rate impact from the natural factors. A relative scale of weighted values was assigned to each criteria class to reflect their relative susceptibility to each type of impact to be rated. The weighted values for each criteria are shown following the map legend.

The next step involved calculation of an index value for each map unit to represent its susceptibility to impact from each of the impacting factors. This was done by multiplying the weighted values which corresponded to each of the criteria classes specified for a given map unit. Since the weighting varied for each of the six impacting factor, a separate calcuation was done for each factor and each map unit.

To provide additional flexibility for planning purposes, six selective materials handling options, outlined below were defined for Whitewood Mine. The selective handling options include respread of salvaged topsoil, subsoil and/or peat and removal of sand and gravel deposits. Since any of these options will alter the performance of the post mining surface, new map symbols were established for each map unit likely to be affected. Calculation of the index values proceeded as for the unaltered spoil, i.e., a new set of weighted values was assigned to the new criteria classes and their multiplication provided an index value reflecting susceptibility to impact of the modified units.

All the index values were converted to first level ratings on a 0 to 9 scale. Zero represent least impact and nine represents greatest impact.

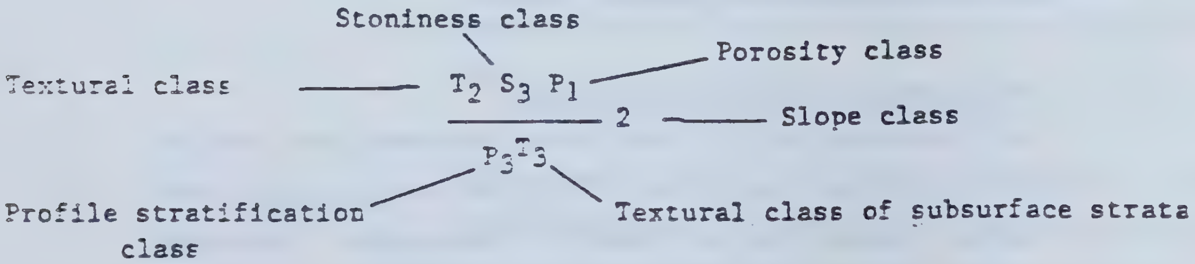
5.5.2 Development of the Post-Mine Map

All existing drill logs were reviewed and several cross-sections developed to illustrate *in situ* overburden composition and general stratigraphy throughout the Whitewood Mine Permit Area. Isopach maps of overburden, Saskatchewan sand and gravel and sandstone

Map Legend and Map Unit Symbol

Criteria	Class	Description
Texture	1	Clayey
	2	Loamy
	3	Sandy
	4	Sandy/Gravelly
Slope	1	0-0.5%
	2	0.5-2%
	3	3-5%
	4	6-9%
	5	10-15%
	6	>15%
Stoniness	1	0-5%
	2	6-15%
	3	16-30%
	4	30-50%
	5	>50% (incl cobbles and boulders)
Porosity	1	Highly porous (many, fine or medium)
	2	Mod. porous (common, medium or coarse)
	3	Channeled (interstitial pores and crevasses)
	4	Not porous (few, fine or very fine)
Profile stratification	1	10 m to contrasting strata
	2	5 m to contrasting strata
	3	1 m to contrasting strata
	4	Several contrasting strata in upper 10 cm
Organic matter	1	>50%
	2	10-50%
	3	2-9%
	4	<2%

MAP SYMBOL


Stoniness class
Porosity class
Textural class
$T_2\ S_3\ P_1$
2
Slope class
P_3T_3
Profile stratification class
Textural class of subsurface strata

Ratings For Each Factor

Texture		Slope		Stoniness		Porosity		Profile		Organic Matter	
Class	Rating %	Class	Rating %	Class	Rating %	Class	Rating %	Class	Rating %	Class	Rating %
TRAFFICABILITY											
Dry Conditions											
1,2	90-100	1,2,3	90-100	1,2	90-100	1	90-100			4	80-100
3,4	60-90	4,5,6	60-80	3,4,5	70-80	2,3,4	60-90			3	40-70
										1,2	10-20
Wet Conditions											
4	80-100	1,2	90-100	4,5	80-100	1	90-100			4	80-90
3	60-80	3,4	60-80	3,2,1	40-70	2,3	50-70			3	70-80
1,2	30-50	5,6	10-30			4	10-30			1,2	10-30
COMPRESSIBILITY											
3,4	90-100			4,5	90-100	4,3	90-100	1,2	80-100	4	80-100
2	80-90			1,2,3	80-90	1,2	70-90	3	60-80	3	60-80
1	70-80							4	40-60	1,2	30-60
ERODABILITY											
Dry Conditions											
4	90-100	1,2	80-100			1	80-100			1	90-100
1	80-90	4,3	50-70			2,3	60-80			2	40-80
2,3	60-80	6,5	30-50			4	20-40			3,4	10-30
Wet Conditions											
4	80-100	1,2	80-100			1	80			1	90-100
3	60-80	3,4	50-70			2,3	40-60			2	40-80
1,2	30-50	5,6	30-50			4	10-40			3,4	10-30
PERMEABILITY "A" (LOW PERMEABILITY - LOW IMPACT)											
Dry Conditions											
1	90-100			4,5	90-100	4	90-100	3,4	80-100	4	90-100
2,3	60-80			3,2,1	70-90	2,3	70-90	2	60-80	2,3	50-90
4	40-60					1	30-50	1	40-60	1	10-30
Wet Conditions											
1	100			4,5	90-100	4	100	3,4	90-100	4	80-90
2,3	70-90			3,2,1	70-90	2,3	80-90	2	70-90	2,3	60-80
4	40-60					1	50-70	1	50-70	1	40-60
PERMEABILITY "B" (HIGH PERMEABILITY - LOW IMPACT)											
Dry Conditions											
4	90-100			1,2	80-100	1	90-100	1	80-100	1	90-100
2,3	70-90			3	60-80	2,3	70-90	2	60-80	2,3	50-90
1	40-60			4,5	40-60	4	30-50	3,4	40-60	4	10-30
Wet Conditions											
3,4	70-90			1,2	80-90	1,2	70-80	1	80-90	1	90-100
2	50-70			3	60-80	3	50-70	2	60-80	2,3	50-90
1	30-50			4,5	30-50	4	30-40	3,4	30-50	4	10-30
ARABLE FARMING											
1,2	90-100	1,2,3	80-100	1,2,3	80-100	2,3	90-100	1,2	90-100	2,3	90-100
3	70-90	4,5	60-80	4,5	50-60	1,4	65-80	3,4	70-90	4,1	70-90
4	60-70	6	50								
REVEGETATION											
1,2	90-100	1,2,3	90-100	1,2,3	80-100	2,3	80-100	1,2	90-100	2,3	90-100
3	60-80	4,5,6	70-90	3,4	70-80	1,4	60-80	3,4	70-90	4,1	70-90
4	50-60			5	60-70						

Mining and Selective Handling Options

Options	Description
1	Basic recontoured spoil - no material rehandle.
2	Topsoil* (15 cm) salvaged and respread.
3	Topsoil and subsoil** (~ 1 m) salvaged and respread.
4	Peat+ salvaged and respread.
5	Gravel≠ salvaged - removed from spoil.
6	Sand salvaged - removed from spoil.

* Loam texture assumed.

** Clay loam texture (clayey) assumed.

+ Amount dependent on volume of peat deposit and size of area of respread.

≠ Assumes any consolidated materials of gravel size or larger associated with the gravel deposit are removed.

thicknesses were generated to further stratify the area into generally homogeneous units. Overlays of the post-mine contour map and a mining technique map, prepared with the aid of Monenco Limited's Mining Department, were then imposed over the area to define final spoil boundaries.

Each unit was named using the map symbol. Some map units represent a range of one or more of the criteria used to define homogenous areas. This occurs when the particular criteria is not a delineating factor of the unit.

5.5.3 Establishment of Criteria Classes

The map legend shows the classes established for each of the criteria. Slope was grouped into the six classes defined in the Canadian System of Soil Classification. Texture was grouped into four general classes which identify materials on the basis of particle size distribution - clayey, loamy, sandy or gravelly.

Stoniness, porosity and organic matter content were subdivided into arbitrarily established, broad classes based on observed spoil characteristics. Broad classes were considered appropriate because specific distinction between units cannot be made with reliability.

Depth to contrasting strata was grouped into four classes on the basis of drill log information from the mined and reclaimed portion of the mine. This before and after mining information was extrapolated to the undisturbed area to indicate the types of stratification which can be expected for the various *in situ* conditions identified.

Weightings of the criteria classes were established and then adjusted following discussion with Earthscape Consultants.

5.5.4 Selective Handling Options

The five selective handling options are discussed in detail below:

1. Selective Handling and Respread of Topsoil (Option 2) - This option assumes that 15cm of loam textured Ah horizon material is respread over the map unit. For rating purposes, depending on the surface texture of the map unit, this material was considered either a contrasting strata or an homogenous influence at the surface. For example, if 15cm of loam is respread over loamy spoil, the influence was considered homogenizing, but if 15cm of loam is spread over gravel, a contrasting strata was considered.

2. Selective Handling and Replacement of Subsoil (Option 3) - This option assumes that about 1m of subsoil and 15cm of topsoil are respread. Ratings thus reflect a homogenous surface metre of material with a loam to clay loam (Class 1) texture.

3. Selective Handling and Respread of Peat (Option 4) - In this scenario, it was assumed that between 5 and 25cm of peat is respread and worked into the spoil surface. The volume of peat added was estimated on the basis of the size and assumed depth of bog from which it was salvaged and the size of the unit onto

which it is respread. Calcuations were done only for units most likely to be affected by peat respread.

4. Salvage of Gravel (Option 5) - This scenario predicts the effects of removal or salvage of large bodies of gravel present in the overburden. The modified unit, therefore, has the characteristics of a non-gravelly material. Calculations were done only for those units in which the presence of gravel (textural class 4) is indicated.

5. Salvage of Sand (Option 6) - In this case, the removal and salavage of significant sand deposits is considered. Again, this option was considered only for those units which indicate the presence of sand (textural class 3) in the map unit symbol.

To calculate a rating for each option, map units were redefined to reflect the difference in spoil properties resulting from the application of each option. The changes in rating attributable to the options were presented as both an absolute value and an additive value. This allowed the addition of any combination of option values to the basic index to provide new map unit indices for the units affected by selective handling.

5.5.5 Ratings - 0 to 9 Impact Scale

The indices for each of the selective handling options were converted into ratings on a scale of 0 (lowest impact) to 9 (highest impact) using the criteria outlined on the following page. These ratings were defined in the pre-mine study as follows:

- High (0-3) for greater than 50% index ratings,
- Moderate (4-6) for indices between 31 and 49%,
- Low (7-8) for indices between 11 and 30%, and
- Very low (9) for indices less than 11%.

To fit the indices onto the straight line curve defined above, each percentage range (>50, 31-49, 11-30, >11%) was divided into the number of units it represented on the 0 to 9 scale. For example, for high (0-3) ratings, the range of 50 to 100% was divided into 4 units so that a sub-range was established for each of the 0, 1, 2 and 3 classes.

5.6 Conclusions

The numerical rating system is consistent and provides a framework for evaluation of patterns of spoil in which weighting values are limited to narrowly defined ranges. Thus, once conditions are specified for each map unit within the framework, map units can be compared in terms of the factors rated.

Flexibility, in that various combinations of selective handling options can be compared is provided by additive nature fo the method. This allows the planner to select the combination of options which provides the best rating for a desired land use or to select the best land use for any specific combination of options. Although values achieved in this way are not absolute, they provide an order of magnitude rating of capability.

Conversion Scale from Indices to First Level Ratings

Index %	First Level Rating	Suitability
90–100	0	High
77–89	1	
64–76	2	
50–63	3	
44–49	4	Moderate
38–43	5	
31–37	6	
21–30	7	Low
12–20	8	
<11	9	Very low

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6.0 SIGNIFICANCE AND FUTURE SYSTEM DEVELOPMENT

It has been agreed by the actors who have been party to the development of this system that it is a significant improvement over past attempts to target reclamation to future land use. It succeeds better than other systems in indicating use feasibility given present technology and is sufficiently flexible to accomodate changing knowledge over time.

The system has significant drawbacks, some of which are identified as follows:

- The system interactive capability can be improved significantly.

- Computer combination of suitability with capability was not necessary in this study area. The suitability mapping could have been used separately to specify land use change or mitigative measures. In larger study areas, however, computer combination is desireable.

Numerous refinements to this planning system for drastically disturbed lands can be suggested from this study. Some of these refinements are suggested below:

- Case studies of individual uses to improve the environmental scoring of the N-2 and N-3 matrices.

- The testing of first level ratings to refine data.

- Pre-mine and post-mine hydrology could be entered in the system as a natural factor.

- Soil and surficial chemistry could be entered in the post-mine system.
- Pixel Size variation could be developed for various scales of mining.
- A visual analysis program could be entered in either the Capability or the Suitablity systems.
- A detailed map and effective sysetm of line plotting by computer would reduce cost.
- A program for prediction of spoil unit inventory and first level ratings could be developed in conjunction with the mining program. This program could then be married to the planning system.

The final land use planning, mining and reclamation decisions are not, however, made by computer systems. An important value of this system to the planning of future land uses in Whitewood related primarily to method.

The planning system succeeded in facilitating the development of relatively detailed, structured, joint decision-making on the part of senior government administration, municipal government administration, and corporate administration. The success of this planning system is best measured in terms of agreement on final land uses, agreement or reclamation targets, and agreement and cost-effectiveness.

SESSION II-B

MINING RECLAMATION

Dr. T. Peters - Chairman

REVEGETATING PRECIOUS METALS TAILINGS IN NORTHERN ONTARIO

Dale Buelow and Tom C. Hutchinson
Department of Botany and Institute for Environmental Studies
University of Toronto
Toronto M5S 1A1

ABSTRACT

Several tailings disposal sites from the milling of gold and silver ores in Northern Ontario were selected to give a range of total arsenic contents. Revegetation in studies were conducted on these in 1980 and 1981 on the assumption that at least part of the reason these areas were devoid of vegetation was related to possible arsenic toxicity.

Three different approaches toward establishing a vegetative cover on these tailings were utilized. These include assessment of the survival and establishment of a selection of non-tolerant and arsenic-tolerant species on variously amended tailings in the field and under glasshouse conditions, assessment of the survival and establishment of a variety of transplanted material from nearby stressed areas into variously amended and unamended tailings in the field, and identification of species invading these tailings at each site and of those treatments which encouraged growth.

Preliminary recommendations for successful revegetation practices have been developed for each site based on the results of these approaches in relation to the physical and chemical growth limiting factors.

INTRODUCTION

In 1980, the known mineral tailings masses in the Province of Ontario covered 24, 767 acres and contained 1, 077, 352,000 tons of tailings, with an estimated 100,243 additional tons of tailings being produced daily, (Hawley, 1980). These wastes are produced collectively by several types of mining operations, namely gold, silver iron-ore, uranium, and base metals.

By far the most prolific tailing production in Northern Ontario has been from the precious metal sector, and the rich finds of these metals in the early part of this century was the primary force responsible for the influx of people and the subsequent development of this part of the province.

Arsenic is a common contaminant of precious metal tailings, and elevated levels of it, along with sulfur, are routinely encountered in Ontario tailings (Hawley, 1980). Since arsenic is often phytotoxic and sulphur can cause acidification, these two elements represent the two most important environmental problems likely to require special attention in reclamation efforts, especially with respect to vegetation establishment.

Assuming that one reason for such tailings being devoid of vegetation may be arsenic toxicity, four precious metal tailings ponds in Northern Ontario, containing a wide range of total arsenic contents, were chosen for revegetation research over the period from 1980 to 1981. Their names and locations, the ores mined, the dates of operation, orebody geology, and the tons of ore milled are given in Table 1. Within the top 20 cm. of the rooting zone, the Lake Shore Property tailings at Kirkland Lake contained the least arsenic (< 30 ppm) followed in order by Siscoe Metals, Gowganda (430-550 ppm), Ken Addison near Virginia town (535-585 ppm), and the Delnite tailings at Timmins (875-5,560 ppm). At these concentrations, arsenic in all four tailings is considerably elevated over the average crustal, and terrestrial, concentrations of 1.8 ppm and 5.0 ppm respectively (Whitacre and Pearse, 1974; Temple et al., 1977; Hawley, 1980).

Our objectives were to identify those physical and chemical factors which were limiting to plant growth at each site and to develop preliminary recommendations for the successful revegetation of each site. Several approaches utilized:

a) A comparative study of both agricultural and metal-tolerant species when planted from seed into untreated and fertilizer treated plots at each site over the 1980 and 1981 growing season.

b) The germination and subsequent root elongation of these trial species on specific tailings from each site under glasshouse conditions was followed.

c) The growth of species transplanted from metal-free substrates into untreated and variously treated tailings at each site was followed over the two growing seasons.

Table 1: Site Description

Name of Mine	Location	Ore Mined	Dates of Operation	Orebody Geology	Tons Of Ore Milled
Kerr Addison Mines, Ltd. (3,9,10,11, 12,13)	48°07.6' N. 79°36.5' W. ~¼ mile SW. of Virginiatown in central McGarry Twp., District of Timiskaming.	Au, Ag	1938-present	The ore is concentrated in the pyritic mineralization of quartz veins found both in carbonatized volcanics and talc-chlorite shists of the Larder Lake "break".	35,400,174
Lake Shore Mines, Ltd. (3,10)	48°07.5'N. 80°01'W. ~1 mile S. of Kirkland Lake in SE. part of Teck Twp., District of Timiskaming.	Au, Ag	1918-1965	Ore taken from the quartz associated veins of the Kirkland Lake "fault" and the complexly intermingled intrusives composed primarily of Algoman syenite porphyry.	16,620,903
Delnite Mines, Ltd. (1)	48°26.1'N. 81°17.7'W. ~3 miles SE. of Timmins in the NW. part of Deloro Twp., District of Timiskaming.	Au, Ag	1937-1964	This particular tailings dump consists of ~½ acre of arsenopyrite which was separated from the original ore and capped with ~ 5 cm. of topsoil.	3,847,364
1908-46 Miller Lake O'Brien Silver Mine 1946-50 Siscoe Metals, Ltd. 1950-71 Siscoe Metals of Ontario, Ltd. 1971-72 United Siscoe Mines, Ltd. (2,4,5,6,7,8)	47°40.5'N. 80°44.5'W. NE. of town of Gowganda in Nicol and Haultain Twps., District of Timiskaming.	Ag, Co	1908-1972	Vein composed of silver with secondary cobalt, iron, and nickel-arsenide minerals at the surface. At depth, the silver mineralization occurs in a gangue primarily with quartz and calcite.	1,147,863

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d) Species which volunteered in the plots were identified, along with those treatments which aided in their establishment.

MATERIALS AND METHODS

A number of physical and chemical site factors were measured, including: bulk density at 0-4 and 5-7 cm depths; texture (% coarse, medium, and fine sand by seiving; % sand, silt, and clay by bouyoucos hydrometer); available water holding capacity (water held at - 1/3 bar minus water held at -15 bar as measured with a ceramic plate extractor); surface temperature (Taylor and Jackson, 1965) as a function of incident solar radiation, this latter measured with a Model 50 Eppley Pyranometer attached to an MJ55 Wescot Microvoltmeter; surface shift of tailings material (at Siscoe Metals only) as monitored by a series of calibrated stakes implanted around the fieldplots at an original depth of 15 cm; pH, specific conductivity, and % organic matter of the top 20 cm. of tailings material; essential elements (N,P,K, Ca,Mg, Na, Cl, Zn, Cu, Mn, Fe) in tailings and several of those known to be toxic when present at elevated levels (As, Al, Co, Ni); and total arsenic in the vegetative positions of species indigenous to each site. Standard techniques were utilized to determine total and water-soluble levels of elements in tailings and vegetation using Neutron Activation Analysis on the Slow-Poke Reactor at U. of T. and Atomic Absorption Analysis on a Perkin-Elmer 460 Spectrophotometer. All samples analyzed by A.A. were digested in a 1:1 mix of HNO_3:H_2ClO_4.

Field Trials:

a) Seeding Experiments

Plots were established on all sites during June, 1980. Eight species were seeded at each site into twelve one-meter square plots/species. This allowed four different treatments, each repeated three times. Unamended (control, C) plots were used at all sites to determine plant responses to the tailings *per se*. Since tailings are very often extremely deficient in such essential nutrients as nitrogen, phosphorus, and potassium, a number of fertilizer amendments were made to the tailings. Both low (335 Kg/ha, F1) and high (1120 kg/ha, F3) levels of a complete fertilizer with the N:P:$\overline{K}$ ratio of 7.7.7 were used, in addition to a low application (335 kg/ha, F2) of a superphosphate with the ratio 0.20.0. Phosphorus is known to interact with arsenic, to which it is chemically similar, and depending on the soil conditions, can either reduce or increase its toxicity (Woolson et. al., 1973; NAS Arsenic Report, 1977). All of the surfaces on which the plots were located were flat and level except Siscoe Metals, where the plots were located down a slope with 10° angle facing northwest.

Table 2 lists the species seeded and the number of seeds sown to each meter square area. The selection of trial species was strongly influenced by the anticipated elevated levels of arsenic. Seed of an arsenic tolerant population of *Agrostis gigantea*, which has colonized the gold mine tailings near Deloro, Ontario, was utilized, in addition to the agricultural strains of *Sorghum sudanense* and *Lolium perenne*, which have been characterized as tolerant to high soluble arsenic levels (V. Zobens, U. of T., pers. comm.; Liebig, Jr., 1966; NRC

Arsenic Report, 1978). These latter two species have also been characterized as aluminum tolerant. *S. sudanense* has the added feature of drought tolerance (Pratt, 1966; Russell, 1973). In addition, seed of the nickel, copper, and aluminum tolerant population of *Deschampsia caespitosa* collected from Alice Lake near Sudbury was also used (Cox and Hutchinson, 1979, 1980).

Tolerant species were utilized in conjunction with the agricultural non-tolerant forage species *Agropyron trachycaulum* and *Phleum pratense*, as well as the legumes *Coronilla varia* and *Lotus corniculatus*. These two legumes were chosen because they have the potential to contribute to the self-maintenance of nitrogen levels in tailings and also because they enjoy popular use in current revegetation efforts in Northern Ontario and Quebec wher they seem to do particularly well at less toxic sites (pers. obs.). The legumes were both seeded dry with the required amount of their respective *Rhizobium inoculant*. A seeding rate of 4 g/m^2 was used where seed quantity permitted.

The number of surviving tillers, their average above ground height, and the number of seedheads produced were recorded for each plot in fall of 1980 and 1981. All species were re-seeded at the time of the fall, 1980 recording with the exception of *A. gigantea* at all sites except Kerr Addison, due to lack of seed. Re-seeding was done because of the high percentage failure of the early summer seed and because fall is the normal time of seed diserpsal.

Table 2: Species and Seeding Rates Used Both Spring and Fall, 1980, in Experimental Plots on Lake Shore Property, Siscoe Metals, Kerr Addison, and Delnite Tailings.

Species	Abbr. Used	No. Seeds Sown/m2		Seeding Rate (g/m2)	
		June	Sept.	June	Sept.
Agropyron trachycaulum	At	1,250		4.0	
Phleum pratense	Pp	10,000		4.0	
Coronilla varia	Cv	1,000		4.0	
Lotus corniculatus	Lc	3,500		4.0	
Sorghum sudanense	Ss	150	110	4.3	4.0
Lolium perenne	Lp	1,200	1,950	2.5	4.0
Agrostis gigantea	Ag	15,000		1.0	
Deschampsia caespitosa	Dc	10,000		2.2	

At the time of the fall 1981 recording, an above-ground biomass was determined at each site.

b) Transplant Experiment

A selection of bare-root cryptogams, herbs, grasses, and woody species were transplanted into the soils under the various treatment regimes mentioned earlier (i.e. C, F1, F2, F3) during June and July of 1980. The June transplants were collected from the surrounding forest while those transplanted in July were collected from nearby gravel pits. At least three individual dumps of each species were transplanted into each treated area to reduce the casualties from the shock effect which transplanting has on subsequent survival and establishment. On the Delnite tailings, number of treatments were increased to include a peat (PE) and a sewage sludge (SS) amendment, each applied at a rate of 40,000 kg/ha. Unfortunately, no analysis of the sludge, obtained from the Whitney-Tisdale Sewage Treatment Plant in Timmins, was available (pers. comm., MOE, Timmins). The peat consisted of a blackened compost obtained from a local peat cutting.

Transplant progression was documented both in the fall of 1980 and 1981. At the time of the last recording, a rating of 0 to 6 was assigned to each species based on relative vigor.

Glasshouse Experiment

A measured quantity of seed of each of the eight trial species was sown on 1 cm of surface tailings material moistened with distilled water in 15 x 1.5 cm. petri plates. Material included:

1. Silica sand control
2. Kerr Addison tailings
3. Lake Shore Property Tailings
4. Siscoe Metals tailings
5. Delnite tailings to which top soil had been added
6. Delnite tailings to which no top soil had been added
7. #5 limed to pH 7.0
8. #6 limed to pH 7.0

Each species/treatment combination was repeated in triplicate. The plates were sealed with parafilm and randomly placed along a bench in the glasshouse. After eight days, the total number of germinated seeds per plate was recorded. The root length (cm) of the germinated seeds was determined for each seedlings if germination was low, or from a quarter or a half sector if counts were high.

RESULTS AND DISCUSSION

Physical Properties

All four tailings were primarily composed of fine sand and silt fractions, i.e. particle diameters within the range of 0.002 to 0.5 mm (Table 3). In all cases, clay contents were negligible. While the Siscoe Metals tailing contained mainly fine sand fractions (0.02-0.5 mm), the Kerr Addison tailing had high, though variable, silt fractions (0.002-0.02 mm). The high silt content in the Kerr Addison tailing is responsible for the compacted conditions detected here (Table 3). With bulk densities between 1.40 and 1.42 in the surface layers, root penetration can be expected to be restricted, as roots will rarely enter a heavy soil, such as the Kerr Addison fines, when the bulk density exceeds 1.50 (Russell, 1973). The high bulk densities detected in the Siscoe Metals and in the top 5 cm of the Delnite tailings reflect the sandy nature of these materials, i.e. although the particles are lying in close contact leaving little pore space, they are by no means cemented together in this fashion, and are, in fact, loosely associated (Brady, 1974). These sandy tailings also had the lowest available water-holding capacities, with the retention capacity of the Siscoe Metals fines averaging roughly 2% over the 20 cm. depth (Table 3). Fines low water retention capacities are drought prone, although this condition is probably offset in the Delnite fines which have an impervious iron pan located at a variable depth of 15-25 cm.

Table 3. Physical Properties of Tailings

Site	Depth	find sand 0.02-0.5mm	*Texture (%) silt 0.002-0.02mm	clay <0.002mm	Depth (cm)	Bulk Density (g/cm3)	%AWHC	Organic Matter %
Lake Shore Property	0-5	63-97	1-37	2	2-4	1.2704	13.5	0.12-0.40
	6-10	78-97	3-22	1	5-7	1.1790	31.9	0.19-0.34
	11-15	56-98	2-43	1			36.4	0.18-0.31
	16-20						35.3	0.34-0.62
Kerr Addison	0-5	20-90	10-80		2-4	1.3995	43.1	1.62-1.95
	6-10	16-68	32-84		5-7	1.4185	34.0	2.08-3.37
	11-15	29-96	3-71				14.0	1.04-2.66
	16-20						24.2	2.31-2.80
Siscoe Metals	0-5	89-91	6-8	1	2-4	1.4472	2.0	0.15-0.30
	6-10	87-92	5-7	1	5-7	1.4733	2.1	0.17-0.21
	11-15	89-92	6-7	1			1.9	0.13-0.15
	16-20						2.1	0.19-0.23
Delnite	0-5	48-56	35-38	5-6	2-4	1.4021	10.9	0.90-2.85
	6-10	32-58	23-39	6	5-7	1.2085	28.1	2.08-2.77
	11-15	39-60	20-24	6-7			34.1	1.83-4.21
	16-20							3.58-5.27

* USDA System of Classification used, medium and coarse sand fractions not shown.

Percent Texture and Organic Matter: Values represent the range as given by three pit profiles per site, two in the case of the Delnite site.

Bulk Density: Values represent the average given by four separate samples obtained in the plot vicinity of each site.

Percent Available Water-Holding Capacity (% AWHC): Values represent the percent water held between - 1/3 and -15.0 bar pressures. Values were determined in duplicate on samples obtained from a single pit profile at each site.

Under all weather conditions, the Siscoe Metals fines attained the highest surface temperatures, followed by the Delnite fines (Table 4). This phenomenon is due to the colour of the tailings, with the slate-black Siscoe Metals tailings absorbing the most incident solar radiatron. This, in combination with an extremely low water-holding capacity, makes the Siscoe Metals fines extremely drought prone.

Table 4: Surface Temperature Attained At Each Site As a Function of Incoming Light Intensity (cal/cm3/min).

Incident Solar Radiation

Site	<0.25		0.26-0.50		0.51-0.75		0.76-1.00		1.01-1.25	
	x	o	x	o	x	o	x	o	x	o
Kerr Addison	*19.7		19.2	7.9	25.3	6.1	27.1	4.6	31.1	3.5
Lake Shore Property	*13.6		20.5	2.1	25.3	1.7	*21.9	27.4		3.1
Siscoe Metals	*26.8		*27.2		34.1	7.1	32.1	5.4	37.2	6.3
Delnite	*18.2		24.7	2.2	27.4	3.0	3.0	5.0	33.2	8.7

All the tailings were found to be highly deficient in organic matter (Table 3). The higher values obtained for the Kerr Addison and all except the top 5 cm of the Delnite fines are attributed to either structural water loss or to the loss of carbonates as CO_2 during combustion, as neither areas supported plant growth.

Since they are extremely sandy and lacking in consolidating agents such as clay or organic matter, the Siscoe Metals fines, which have not been leveled are prone to severe wind erosion. The surface of these tailings varied in depth by as much as 5 cm, either increasing or decreasing, depending on the wind direction. Plants establishing on these tailings have to contend with the associated problems of sandblasting and surface shift. There almost complete absence suggests that this degree of erosion and burial is too much to cope with and erosion control is mandatory in their reclamation.

Chemical Properties

Most tailings had a slightly alkaline pM, with the exception of Delnite spore (Table 5). The extremely acidic nature of this waste (pH 2.23-3.12) is caused by the oxidation of pyrite and the associated generation of sulphuric acid. The waste is composed of arsenopyrite which was separated fom the original orebody and placed in an isolated dump.

The conductivity values were generally high or very high for soils. Only those monitored in the Siscoe Metals tailings would be virtually harmless for plant growth, i.e. below 2 mmhos/cm (Table 4) (Eaton, 1966; Waisel 1972; Russell, 1973). Lake Shore Property and Delnite tailings would be restrictive to the growth of salt-sensitive plantes, i.e. between 2-4 mmhos/cm (Hoid). Conductivity was varied in the Kerr Addison tailings, with some areas being

Table 5: Chemical Properties of Tailings

				ELEMENTAL CONTENTS (ppm)														
				TOTAL						WATER-EXTRACTABLE								
Site	Depth	pH	S.C. (mmhos/cm)	Ca:Mg	N	K	Na	Cl	P	Ca	Zn	Cu	Mn	Fe	As	Ni	Al	Co
Lake Shore Property	0-5	8.04	2.49-3.43	1.17	28	18510	19485	243	<0.25	53	nd	nd	0.37	nd	2.5	nd	2.4	0.06
	6-10	7.99	2.81-3.37	1.18		18765	19755	240		50			0.40		2.4		1.5	0.05
	11-15	7.96	1.99-2.50	1.13	20	19215	19215	247		51			0.30		2.0		1.5	0.04
	6-20	7.79	2.59-3.12	1.16		18270	19050	270		41			0.33		2.1		2.0	0.04
Kerr Addison	0-5	7.85	0.90-4.17	0.80	96	3350	14805	290	<0.25	208	nd	nd	0.20	nd	2.0	nd	1.6	0.10
	6-10	7.79	0.82-5.34	0.79		2880	15535	277		290			0.23		2.2		2.0	0.16
	11-15	7.72	0.46-2.68	0.79	70	2555	16370	297		396			0.23		1.7		2.1	0.28
	16-20	7.78	0.61-2.12	0.78		2110	16075	258		620			0.20		1.8		2.0	0.13
Siscoe Metals	0-5	8.35	0.10-0.15	1.06	40	6025	17350	352	<0.25	428	nd	nd	0.10	nd	2.0	nd	2.4	0.04
	6-10	8.39	0.10-0.12	0.94		6320	17330	418		265			0.17		2.8		3.1	0.04
	11-15	8.49	0.10-0.11	0.97	28	6165	17075	347		445			0.17		4.2		2.7	0.04
	16-20	8.41	0.11-0.15	1.04		6135	16230	360		1345			0.17		5.0		2.8	0.04
Delnite	0-5	3.12	2.37-3.27	2.83	300	4240	12985	192	<0.25	1535	0.35	1.8	2.70	53	3.6	3.7	20.8	0.56
	6-10	2.59	2.98-3.09	3.44		2390	8545	185		1545	0.25	1.7	1.65	56	3.2	2.6	18.2	0.44
	11-15	2.42	3.34-3.64	3.56	750	3380	7460	185		1505	0.60	3.1	4.55	319	5.5	7.1	25.0	0.79
	16-20	2.23	3.45-3.94	3.70		3465	6365	175		1500	1.00	4.9	4.00	353	12.2	8.0	31.2	1.14
Average Crustal Occurrence: a						200-5000 x=1500^c	25900	28300			1.0^d							
Suggested Range in Nutrient Solutions For Angiosperms: b												50-350	0.02-0.20	0.01-0.10	0.01-1.0	0.50-50.0		
Toxic Effects in Nutrient Solutions: b														>1.0	>1.0	>1.0	>1.0	

Values represent the average or range obtained from three pit profiles per site, two in the case of the Delnite site.

a = Hawley, 1980 b = Bowen, 1966 c = Brady, 1974 (Range Common to Soils) d = Bingham, 1966 (a response to phosphorus if < 1.0 ppm extracted by water-soluble method).

restrictive to the yields of most plants that were not strongly salt tolerant, i.e. above 4 mmhos./cm (Ibid). However, both the Kerr Anderson and Lake Shore Property tailings develop salt crusts, or efflorencences, during the growing season indicating that salts do become much more concentrated on and in the surface layers than measured.

All of the alkaline tailings, i.e. Kerr Addison, Lake Shore Property, and Siscoe Metals, were chemically similar (Table 5). All three may be characterized as deficient in the macronutrients nitrogen, phosphorus, and potassium, with the possible exception of potassium in the Lake Shore Property tailings. These three tailings may also be deficient in the micronutrients zinc, copper, iron, and possibly manganese, the former three being below the detection limit of our A.A. Spectrophotometer in water extracts. These tailings all had elevated chloride levels and potentially phytotoxic levels of both "available" arsenic (1.7 - 5.0 ppm) and aluminum (1.5 - 3.1 ppm). Although plants vary in their sensitivity to both these elements, significant reductions in root growth have been found to occur at levels of water-soluble aluminum as low as 2 ppm (Whitby and Hutchinson, 1974). Also, Porter and Peterson, 1977, reported that the root growth of non-tolerant clones of Agrostis tenuis were significantly affected by 5 ppm. arsenic, as arsenate, in solution culture and Rocovich and West, 1975, stated that non-tolerant clones of Andropogon scoparius were unable to grow in solution cultures containing as little as 1 ppm. arsenic.

The Delnite tailings are chemically quite different from the other three (Table 5). They are very acidic and while this tailing can be characterized as deficient in both potassium and phosphorus, the nitrogen levels seem favourable, and are likely to reflect the use of an ammonium extractant in processing, as the source certainly cannot be organic. For such an acidic tailing, the Delnite waste has an unusually high calcium content, with water-extractable levels in excess of 1500 ppm (Bradshaw and Chadwick, 1980). The high calcium levels can be explained by the presence of an impervious iron pan deeper in the profile, which acts to restrict normal drainage losses. Most of the calcium is thought to be in the form of sulfate salts, although chlorides and arsenates are also likely to occur.

The high calcium levels which have accumulated resulted in unfavourable Ca:Mg ratios, i.e. 3:1 which may indicate a potential magnesium deficiency (Russell, 1973). Accompanying the high calcium levels in the water extracts were potentially phytotoxic concentrations of zinc (0.25 - 1.00 ppm), arsenic (3.2 - 12.2 ppm), nickel (2.6 - 8.0 ppm), aluminum (18.2 - 31.2 ppm), and cobalt (0.4 - 1.1 ppm). Cobalt was found to markedly inhibit root growth of several vegetables at concentrations < 5 ppm (Whitby and Hutchinson, 1974). In this same study, copper was found to significantly reduce growth at levels as low as 2 ppm and nickel at 2 ppm reduced the root growth of tomato by 70% (Ibid). However, the difficulty with specifying levels at which these two elements become toxic is complicated by the fact that their toxicities are more than additive when they occur together (Ibid). Likewise, soluble levels of zinc are commonly toxic in the range 1 - 10 ppm, but zinc is much more toxic when in combination with copper, with which it acts synergistically (Down and Stocks, 1978). Iron becomes potentially damaging to plant growth when in excess of 50 ppm, but at this low pH, much of the iron will occur in the ferric state, which is decidedly more toxic (Ibid, Rorison, 1980).

TABLE 6: PERCENT SURVIVORSHIP (%S), AVERAGE HEIGHT (cm)(Ht), AND NUMBER OF SEEDHEADS (Sh) PRODUCED BY EACH TRIAL SPECIES DURING THE 1980 GROWING SEASON ACCORDING TO TREATMENT.

Site	Trmt	Agropyron trachycaulum			Phleum pratense			Coronilla varia			Lotus corniculatus			Sorghum sudanense			Lolium perenne			Agrostis gigantea			Deschampsia caespitosa		
		%S	Ht	Sh	%S	Ht	Sh	%S	Ht	Sh	%S	Ht	Sh	%S	Ht	Sh	%S	Ht	Sh	%S	Ht	Sh	%S	Ht	Sh
LAKE SHORE PROPERTY	C	21.7	7.7		0.6	2.3		10.6	4.0		0.9	5.7		36.2	16.7		21.5	3.0		0.8	1.0		1.7	1.0	
	F1	18.1	11.0		0.3	3.0		8.5	2.0		0.4	2.7		18.2	8.0		26.4	*16.7	*3.7	0.7	5.3		1.0	7.0	
	F2	14.8	8.7		0.1	2.3		8.1	2.0		0.8	4.0		30.4	15.0		28.0	*14.3	'2.0	0.4	3.7		1.1	3.0	
	F3	19.6	12.7		0.1	3.7		3.8	2.0		0.6	7.7		17.1	*26.3		14.0	'12.0	0.7	0.7	*8.7		1.4	**8.7	
KERR ADDISON	C	14.6	9.0		0.2	4.3					0.1	0.3		17.3	14.3		2.6	3.0		0.3	0.7		0.2	2.3	
	F1	12.6	18.7		0.2	11.7					0.1	4.7		18.0	23.0		9.3	25.3	2.3	0.4	15.7		0.4	*7.0	
	F2	11.8	16.7		0.6	6.3					0.2	7.0		20.9	20.3		14.8	25.0	4.0	0.7	12.7		0.7	*6.3	
	F3	14.8	*38.3	**11.7	0.5	**38.3	**4.0				0.1	7.5		22.2	**85.0		9.5	**60.0	**27.3	0.5	*34.3		0.6	*10.0	
SISCOE METALS	C	7.3	3.3		1.3	1.7		0.2	1.0		0.2	1.0					1.9	2.7		0.7	0.3		0.02	0.3	
	F1	17.5	*7.0		1.9	3.0		0.8	1.7		0.5	0.7		4.9	*6.0		15.4	3.0		0.5	1.3		0.1	1.3	
	F2	15.8	*8.0		1.5	3.7		1.3	1.7		1.1	1.0		2.0	2.0		6.5	2.3		0.2	0.3				
	F3	14.6	*8.3		2.9	3.0		1.8	2.0		0.4	1.0		14.2	*7.0		19.3	3.0		0.5	1.7				
DELNITE	C	12.9	5.5		1.6	1.0		1.9	1.0		3.9	2.0		22.3	11.0		16.0	3.5		0.3	0.5				
	F1	13.1	6.5		5.5	*9.0		1.4	1.0		4.1	3.0		23.7	15.5		28.1	8.0		2.2	12.0		0.1	5.0	
	F2	13.7	6.0		2.7	4.0		1.8	1.0		2.1	2.0		27.7	12.0		31.4	8.5		0.9	5.0		0.1	3.0	
	F3	18.4	9.0		4.3	*10.5		7.8	1.0		1.0	2.0		39.0	15.5		21.1	11.0		2.2	*17.5		0.2	4.0	

Results based on $3m^2$ plots/treatment/species, $2m^2$ plots/treatment/species at the Delnite site.
The ranked mean statistic (Duncan's Multiple Range Test) is shown as a probability based on log n growth for hieght and seedhead production, and based on the percent surviving out of the number of seeds sown for percent survivorship.

* = results are significantly different at $p<0.05$
** = results are significantly different at $p<0.01$
' = results are not significantly different from indicated character at the given confidence level.

Treatment (Trmt): C = untreated
F1 = 335 kg/ha 7.7.7
F2 = 335 kg/ha 0.20.0
F3 = 1120 kg/ha 7.7.7

Vegetation Trials

The species which showed the best growth from seed on this waste were *Sorghum sudanense*, *Agropyron trachycaulum*, *Lolium perenne*, and the arsenic-tolerant *Agrostis gigantea*, with the maximum response being to the high 7.7.7 fertilizer additions (Tables 6,7). The predominant growth in the 1981 growing season was of perennials from the previous year. Fall 1980 sown seed failed to germinate at all sites.

Coronilla varia could not survive from seed on the Kerr Addison tailing despite fertilizer additions (Table 6), and it is evident from bioassays (Figure 1) that germination of this species is extremely inhibiited on this waste. Although all species were inhibited in terms of subsequent root growth (Figure 2), Phleum pratense was most inhibited, which may explain its poor field performance in all but high 7.7.7 fertilizer-treated tailings (Table 7). Although, from bioassay, *Lotus corniculatus* was not inhibited in terms of either germination or subsequent root growth, this species did not do well in the field (Tables 6, 7), suggesting that it is inhibited at a later stage in the growth process.

The chemical factor(s) which inhibit the germination of *C. varia* seed and the subsequent root growth of all the test species are not thought to be either arsenic or aluminum toxicity, although these elements were both present in potentially phytotoxic concentrations. The commercial grass, *Agropyron trachycaulum*, showed the best growth on this waste in the absence of any tolerance to elevated levels of either arsenic or aluminum (Table 7). In addition, several species, i.e. *Melilotus alba*, *Agrostis gigantea*, and *Poa palustris*, transplanted from metal-free substrates grew well in this waste, even when unamended. This again indicates that metal toxicity is probably not the factor inhibiting the growth of several species (Table 8).

The inhibitory factor in this waste is thought to be sodium chloride salinity. All of the major species which volunteered in the plot areas (i.e. *Atriplex patula*, *Chenopodium glaucum*, *C. album*, *Hordeum jubatum*, and *Puccinellia distans*) are well-known halophytes which are tolerant to elevated sodium chloride levels (Table 9) (Britton and Brown, 1913; Sutcliffe and Baker, 1974; Dore and McNeill, 1980). In addition, because negligible colonization and growth by the trial species occurred in untreated plots, the poor tilth of the Kerr Addison tailing is also thought to be limiting to growth (Tables 7,9). This problem may be effectively overcome by the addition of high 7.7.7 feritlizer which allows healthy root growth (Table 7).

Lake Shore Property

The site was originally selected as a low-arseic control, as it had the lowest total arsenic contents. In the event, the Lake Shore Property tailing was chemically very similar to Kerr Addison in both potential metal toxicities and in having a salinity problem.

As with Kerr Addison tailings, the major growth-limiting factor seemed to be sodium chloride salinity, as many of the same halophyte species colonized the plots at both sites, i.e. *Pucinellia distans*, *Hordeum jubatum*, and *Atriplex*

Table 7: ABOVE GROUND BIOMASS (g) PRODUCED BY EACH TRIAL SPECIES BY FALL, 1981, ACCORDING TO TREATMENT.

Site	Trmt	*Agropyron trachycaulum*	*Phaleum pratense*	*Coronilla varia*	*Lotus corniculatus*	*Sorghum sudanense*	*Lolium perenne*	*Agrostis gigantea*	*Deschampsia cespitosa*
Lake Shore Property	C	1.9	0.6	NG	0.3	NG	0.9	NG	NG
	F1	19.1	5.8		NG		38.1	14.7	0.1
	F2	3.5	4.1		0.6		7.9	2.5	0.2
Kerr Addison	C	0.2	0.1	NG	NG	NG	0.1	NG	NG
	F1	5.9	NG				9.5	6.1	1.5
	F2	17.0	NG				3.0	6.2	2.6
	F3	**167.7	20.0				**57.8	**64.4	**34.2
Siscoe Metals	C	NG	NG	NG	NG	NG	NG	NG	NG
	F1								
	F2								
	F3								
Delnite	C	0.8	NG	NG	0.5	NG	NG	NG	NG
	F1	1.7	'9.0		0.5		1.2	'37.0	1.3
	F2	1.5	1.2		0.5		2.9	7.7	0.6
	F3	3.3	*19.3		0.7		5.3	*98.1	4.3

Results based on three meter square plots/treatment/species, two meter square plots/treatment/species at Delnite.

The ranked mean statistic (Duncan's Multiple Range Test) is shown as a probability based on log n growth:

* = results are significantly different at $p < 0.05$
** = results are significantly different at $p < 0.01$
' = results are not significantly different from indicated character at the indicated confidence level.

Treatment (Trmt): C = untreated
F1 = 335 kg/ha 7.7.7
F2 = 335 kg/ha 0.20.0
F3 = 1120 kg/ha 7.7.7

NG = no growth in plots

patula (Table 9). The difference is that all of these species were prominent colonizers of Lakeshore Property before plot establishment, indicating that, with good tilth, no requirement other than a tolerance to elevetated sodium chloride levels is necessary to promote good growth, although fertilizer additions can considerably speed the rate at which colonization taken place (Table 9). These tailings-adapted species are far more productive and persistent than any of the introduced species, all of which required high 7.7.7 fertilizers dressings to grow well (Table 7).

The conjecture that sodium chloride salinity, and not metal toxicity, is the primary growth-limiting factor on the Lake Shore Property tailing is supported by the similar growth responses given by the trial species at both sites, any differences most probably being due to the difference in tilth between the two (Tables 6,7; Figures 1,2). It is further supported by the good growth of both *Agrostis gigantea* and *Hordeum jubatum*, transplanted from metal-free substrates, in unamended tailings at this site (Table 8).

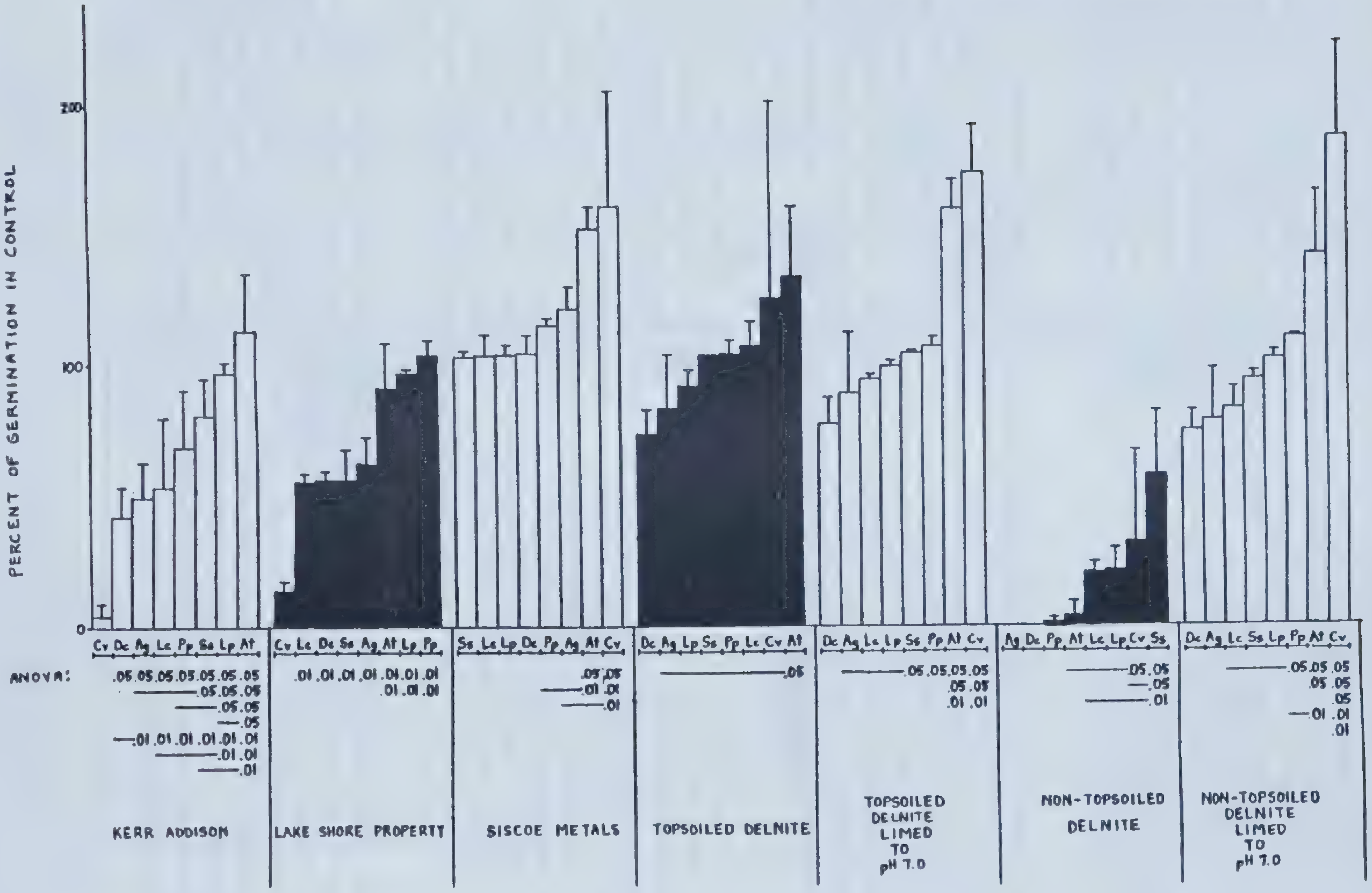
Siscoe Metals

Despite fertilizer additions, none of the trial species grew well in the first growing season and all completely failed in the second growing season (Tables 6,7). This poor growth was not the result of chemical inhibition, as both the germination and subsequent root elongation of all the trial species on this waste under glasshouse conditions was excellent (Figures 1,2). All species germinated better on this tailing than in their silica sand controls and all except *Agropyron trachycaulum* and *Sorghum sudanense* produced their best root growth here, strongly indicating that metal toxicity is not a factor preventing growth.

The factor(s) which are preventing growth at this site are thought to be physical in nature, and to include the lack of a consolidated surface, as well as a tendency toward droughtiness, neither of which can be overcome by fertilizer additions. The use of calibrated stakes showed that the tailings surface could shift by as much as 5 cm, either increasing or decreasing, depending on the wind direction. The fact that the only species beginning to colonize this waste along the perimeter was *Festuca arundinacea*, which has the ability to secure the tailings with its root system against the erosive force of the wind, strongly suggests that the lack of a consolidated surface, along with its associated problems of sandblasting and uprooting, is probably the single most important factor preventing plant growth. Because this species was able to colonize in the absence of fertilzer amendment and because fertilizer additions had no influence on the subsequent growth of the transplanted species, this suggests that fertilizer additions may not be necessary to implement growth here (Table 8).

Droughts may, however, present a problem to the establishment of vegetation which are not so adapted, as this waste has a low water retention capacity and experiences high evaporation losses from the surface layers (Tables 3,4).

Figure 1 : Species Differences in Terms of Germination. Values Depict the Mean Germination on Each Tailings Medium by Each Species as a Percentage of Germination in a Silica Sand Control. Results of Analysis of Variance Between Species Appears Below.



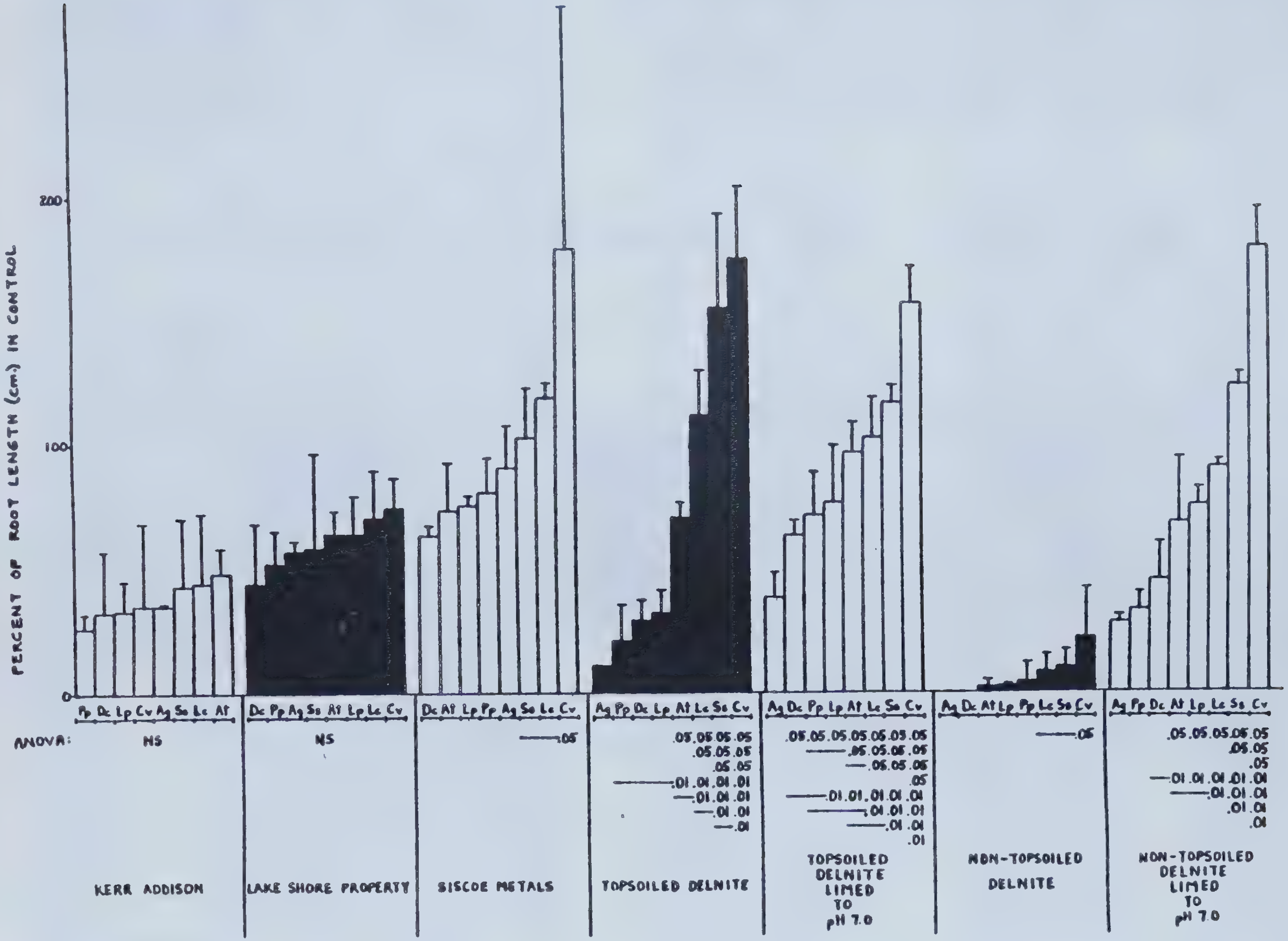
SPECIES:

At = *Agropyron trachycaulum*
Pp = *Phleum pratense*
Cv = *Coronilla varia*
Lc = *Lotus corniculatus*
Ss = *Sorghum sudanense*
Lp = *Lolium perenne*
Ag = *Agrostis gigantea*
Dc = *Deschampsia caespitosa*

.05 = results significantly different with 95% confidence
.01 = results significantly different with 99% confidence
—— = results are not significantly different from indicated character.

The ranked mean statistic (Duncan's Multiple Range Test) is shown as a probability based on percent of performance in silica sand control.

Figure 2 : Species Differences in Terms of Root Elongation. Values Depict the Mean Root Length Produced on Each Tailings Medium by Each Species as a Percentage of Root Growth in a Silica Sand Control. Results of Analysis of Variance Between Species Appears Below.



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At= *Agropyron trachycaulum*
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Ag= *Agrostis gigantea*
Dc= *Deschampsia caespitosa*

.05 = results significantly different with 95% confidence
.01 = results significantly different with 99% confidence
— = results are not significantly different from indicated character
NS = results are not significantly different from each other

The ranked mean statistic (Duncan's Multiple Range Test) is shown as a probability based on percent of performance in silica sand control.

Delnite

Despite the presence of potentially phytotoxic concentrations of each of zinc, copper, iron, arsenic, nickel, aluminum, and cobalt, metal toxicity does not exclude plant growth on this waste. Of the trial species, Phleum pratense, an agricultural strain with no known metal tolerances, was able to growth quite well in this waste when provided with a complete N.P.K. fertilizer (Table 7). Also, 9/10 of the species transplanted from metal-free substrates were able to persist in untreated tailings, five of these (Poa palustris, P. compressa, Agrostis gigantea, Hordeum jubatum, and Salix pyrifolia) exceptionally well, strongly suggesting that the populations of them which have already colonized this waste are not metal tolerant (Table 8). In addition, several familiar weedy species, i.e. Taraxacum officinale, Anaphalis margeritacea, and Trifolium pratense, were observed casually colonizing untreated plots during the course of the experiment (Table 9).

The addition of a layer of sandy topsoil to this waste was effective in ameliorating the available levels of toxic metals, to the extent that their inhibitory effects toward root growth were no longer sufficient to overcome the ability of many plants to take advantage of the levels of available calcium present and grow. This is portrayed in Figures 1 and 2 both in terms of germination and root elongation, between the Non-Topsoiled and Topsoiled Delnite spoils. It is readily evident that the addition of sandy topsoil was roughly as effective as liming the media in promoting improved germination and root growth in the trial species.

That the levels of available calcium are sufficient to overcome metal ion antagonism toward root growth is supported by the fact that calcicoles, such as Hordeum jubatum, which are intolerant of low levels of available calcium, have colonized this tailing (Kuja and Hutchinson, 1979; Hutchinson and Kuja, 1979). Soil modifying factors such as calcium play a large role in determining whether or not metals will be toxic to plant growth. For example, studies conducted by Hogan et al., 1977, on the populations of Agrostis gigantea which have colonized copper and nickel contaminated sites in Sudbury have shown that non-tolerant populations (root growth is markedly inhibited by as little as 0.1 ppm available copper) have colonized areas high in copper, but only where the pH was neutral (pH 6-7).

The fact that colonization and transplant growth was possible in untreated waste further suggests that fertilizer additions are not necessary to promote plant growth on the Delnite tailings. This, again, suggests that the use and encouragement of native tailings adapted species is superior to the use ofintroduced strains, all of which required high 7.7.7 fertilizer additions to grow well (Tables 6,7). Despite fertilizer additions, several could not persist, showing complete or near failure the second growing season. Among these were Coronilla varia, Lotus corniculatus, and Agropyron trachycaulum (Table 7).

The response of the agricultural strains to the fertilizers could be anticipated since they have high growth rates and high nutrient demands (Elias and Chadwick, 1979). The response shown by the arsenic-tolerant Agrostis gigantea to fertilizer additions is compatable with the results of work that has

Table 8 : Transplant Performance By Site Under Various Treatment Regimes as Documented September, 1981. (Rating 0=none survived, 6=vigorous and spreading)

Site	Ha.	Species	C	F1	F2	F3	SS	Pe
Lake Shore Property	G	*Equisetum arvense*	1.04	0	0	0		
	B	*Epilobium angustifolium*	0	0	5.10	0		
	B	*Oryzopsis asperifolia*	0	3.08	3.10	3.08		
	B	*Schizacne purpurascens*	0	5.33	5.38	5.34		
	G	*Agrostis gigantea*	4.68	4.84	5.20	5.31		
	G	*Hordeum jubatum*	4.38	4.53	5.27	5.20		
	B	*Salix humilis*	3.00	2.70	0	2.00		
	B	*Populus tremuloides*	0	0	0	1.00		
	G	*Alnus crispa*	0	0	0	0		
Kerr Addison	B	*Epilobium angustifolium*	0	0	0	0		
	G	*Melilotus alba*	4.10	4.59	5.69	4.15		
	G	*Polygonum cilinode*	0	2.00	0	5.15		
	B	*Agrostis gigantea*	5.05	5.48	5.31	5.58		
	G	*Agrostis scabra*	0	0	0	0		
	B	*Poa palustris*	5.52	5.55	5.47	5.66		
	B	*Populus balsamifera*	0	0	0	1.00		
	B	*Salix pyrifolia*	1.00	1.00	2.00	2.00		
	B	*Populus tremuloides*	0	1.00	0	0		
	G	*Alnus crispa*	0	0	4.00	4.00		
Topsoiled Delnite	G	*Equisetum arvense*	1.00	1.00	0	4.00	2.00	2.00
	B	*Vicia cracca*	2.00	0	3.00	3.00	3.00	3.00
	B	*Poa compressa*	5.32	5.48	5.33	5.99	5.76	5.64
	B	*Poa palustris*	4.17	4.16	4.10	4.22	4.12	4.12
	G	*Agrostis gigantea*	5.30	5.15	4.76	5.70	5.23	5.23
	G	*Hordeum jubatum*	4.06	4.44	5.12	4.85	5.16	5.15
	B	*Populus balsamifera*	1.00	0	0	1.00	0	0
	G	*Populus tremuloides*	0	0	0	3.00	0	0
	B	*Picea glauca*	2.00	2.00	2.00	2.50	2.00	2.00
	G	*Salix pyrifolia*	3.00	2.00	0	3.00	3.00	3.00
Siscoe Metals	G	*Equisetum arvense*	0	0	0	0		
	B	*Epilobium angustifolium*	0	0	0	0		
	G	*Agrostis gigantea*	4.09	4.09	4.70	4.70		
	G	*Agrostis scabra*	1.00	0	0	0		
	B	*Poa compressa*	5.12	3.08	4.22	5.30		
	B	*Festuca arundinacea*	4.14	4.16	0	0		
	B	*Oryzopsis pungens*	1.06	0	0	0		
	B	*Populus tremuloides*	0	0	0	0		
	B	*Betula papyrifera*	0	0	0	0		
	G	*Salix humilis*	1.00	1.00	1.00	1.00		
	G	*Alnus crispa*	0	0	0	0		
	G	*Myrica gale*	0	0	0	0		

Ha. = habitat
B = transplanted from sparse boreal forest soil development
G = transplanted from a gravel pit

C = untreated
F1 = 335 kg./ha. 7.7.7
F2 = 335 kg./ha. 0.20.0
F3 = 1120 kg./ha. 7.7.7
SS = 40,000 kg./ha. liquid sewage sludge
Pe = 40,000 kg./ha. peat

been conducted by Goodman et al., 1973 and Smith and Bradshaw, 1979. These authors have shown that fertilizer additions are necessary for the establishment of tolerant individuals on similarly contaminated wastes, but they respond much faster and persist much longer than the normal commercial varieties, even with minimal fertilizer additions, as can be seen in Table 7. While metal tolerance is not necessary for growth in this waste, the superior growth of the metal tolerant A. gigantea may reflect it tolerance of other edaphic factors present in the tailings (Gadgill, 1969; Bradshaw, 1975).

The incorporation of the Delnite tailings into the study sites provides a unique insight into the reclamation of pyritic wastes which present potential oxidizable acidity problems. The present method of reclaiming these wastes with vegetation involves massive liming, up to 200 t/ha (Gemmell, 1975). This technique still does not guarrantee a successful plant cover, as massive liming causes nutrient immobilization problems and the ongoing process of sulphuric acid generation causes an eventual return to the original acidity, with the concomitant loss of the vegetative cover (Ibid).

It is possible that acid generating fines may be able to be reclaimed through the creation of a calcium excess in tailings, perhaps by incorporating finely ground rock high in calcium, but not containing the calcium in carbonate form. The waste could then either be diluted with sand or capped with a heavy dressing of sand, preferably with a thin layer of free draining gravel placed beneath it to prevent excessive metal migration. For the use of this technique, it would be preferable that an impermeable hardpan be present lower in the profile to retard excess calcium loss by leaching, as otherwise the calcium source would have to be continually supplied to assure a high available calcium content.

Further Considerations

Plants which grow on arsenic - contaminated soils have been shown to accumulate high levels of arsenic in their tissues without ill effect. This situation is most extreme for arsenic tolerant plants. Porter and Peterson, 1977, reported tolerant Agrostis tenuis plants to contain as much as 3,460 ppm. As in their tissues from mine spoil containing > 20,000 ppm As. However, non-tolerant plants also accumulate arsenic in excess of the 1-2 ppm As normally found (N.R.C. Arsenic Report, 1978). Temple et al., 1977 found that grasses within 700 m of a secondary lead smelter had accumulated up to 62 ppm As in their tissues, from soils containing up to 2,000 ppm As, without ill effect.

In this study, plants colonizing these precious metal tailings accumulated arsenic to quite high levels in their tissues without ill effect, even though they are not suspected to be metal tolerant (Table 10). For example, arsenic ranged from 10 ppm in the shoots of various grasses sampled from Lake Shore Property to approximately 20 ppm, 24 to 44 ppm, and 170-363 ppm in the shoots of grasses growing on Kerr Addison, Siscoe Metals, and Delnite tailings respectively.

The primary concern over these accumulations is that they represent a potential health hazard to grazing wildlife, especially if this grazing is prolonged. One study has actually documented, to some extent, the danger

Table 9 : Total Number of Colonizing Individuals
per Treated Area* per Site as
Recorded September,1981+.

		TREATMENT						
Site	Species	C	F1	F2	F3	Pe	SS	L
LSP	*Taraxacum officinale*	2	0	2	2	0		
	Atriplex patula	12	21	19	41	4		
	Polygonum erectum	1	5	5	14	0		
	Hordeum jubatum cl.	27	7	41	49	0		
	Puccinellia distans cl.	9270	16920	32020	4470	11940		
	Populus balsamifera	0	0	0	1	0		
KA	*Taraxacum officinale*	2	8	2	4	0		
	Solidago graminifolia	0	0	0	11	0		
	Carex aurea cl.	0	0	0	3	0		
	Atriplex patula	3	86	1	12	0		
	Chenopodium glaucum/ album complex	0	714	890	2325	0		
	Puccinellia distans cl.	2	24	34	73	0		
	Hordeum jubatum cl.	0	14	33	177	0		
	Festuca arundinacea cl.	0	0	3	0	0		
DEL	*Taraxacum officinale*	2	0	0	0	5	0	0
	Anaphalis margaritacea	2	0	0	0	0	0	0
	Achillea millefolium	0	1	0	0	1	0	0
	Trifolium pratense	2	0	0	0	1	0	0
	Hieracium aurantiacum	0	0	0	0	0	3	0
	Vicia cracca	0	0	1	0	0	0	0
	Phleum pratense cl.	0	0	0	0	0	2	0
	Hordeum jubatum cl.	0	5	4	35	1	3	0
	Salix humilis	0	2	0	0	1	0	0
	Populus balsamifera	0	2	0	0	5	0	0

+ = Siscoe Metals did not become colonized on the study area
cl. = clump

	*Treated area (m^2)		
Treatments	KA	LSP	DEL
C = untreated	28	29	20
F1 = 335 kg./ha. 7.7.7	28	29	20
F2 = 335 kg./ha. 0.20.0	28	29	20
F3 = 1120 kg./ha. 7.7.7	28	29	20
Pe = 40,000 kg./ha. peat	27	24	26
SS = 40,000 kg./ha. liquid sludge	--	--	11
L = 71.000 kg./ha. pulverized limestone	--	--	24

Table 10: Total Arsenic Content (ppm.) in Vegetative Portions of Species Indigenous to Each of the Four Sites.

Classification	Species	Sample	Kerr Addison x̄	Kerr Addison σ	Lake Shore Property x̄	Lake Shore Property σ	Siscoe Metals x̄	Siscoe Metals σ	Topsoiled Delnite x̄	Topsoiled Delnite σ
Equisetaceae	*Equisetum arvense*	Roots			+3.4	0.2	73.6	3.7		
		Shoots	15.3	2.1	2.8	0.1	46.3	2.2		
	Equisetum palustre	Roots			3.6	0.1				
		Shoots			4.3	0.1				
	Equisetum variegatum	Roots					264.1	17.2		
		Shoots	56.9	6.3			339.7	14.8		
	Equisetum laevigatum	Roots					127.5	9.5		
		Shoots					107.0	1.7		
Angiospermae - Gramineae	*Hordeum jubatum*	Roots	19.5	1.9	4.7	0.4			183.2	4.0
		Stems	3.1	0.3	3.1	0.1			61.2	2.3
		Leaves	12.8	1.3	+2.8	0.4			281.9	9.4
		Inflorescences	5.2	0.7	3.1	0.2			19.7	2.4
	Agrostis gigantea	Roots	35.0	1.8	3.9	0.1	+58.4	3.4	18.4	5.5
		Stems	4.5	0.3	2.4	0.1	7.2	0.6	15.4	0.7
		Leaves	11.2	1.2	2.7	0.2	25.4	1.1	112.2	6.3
		Inflorescences	5.7	0.6	3.1	0.1	10.8	0.1	41.1	2.4
	Puccinellia distans	Roots			+3.2	0.2				
		Stems			+2.8	0.2				
		Leaves			+8.6	0.9				
		Inflorescences			2.4	0.4				
	Calamagrostis canadensis	Roots					34.8	2.3		
		Stems					2.5	1.3		
		Leaves					12.6	1.3		
		Inflorescences					8.6	1.8		
Angiospermae - other	*Populus tremuloides*	Foliage	3.6	0.1	1.8	0.1	8.6	0.1	15.5	1.0
	Salix spp.	Foliage	6.3	0.6	2.5	0.1	6.0	0.1	10.6	0.2
	Populus balsamifera	Foliage	2.2	0.4	2.3	0.2	10.0	0.2	21.4	1.1
	Betula papyrifera	Foliage	7.2	1.0			16.7	0.8	24.2	1.8
	Cornus stolonifera	Foliage					5.4	0.3		

All values represent the average of three determinations.
+ = two determinations.

prolonged ingestion of an arsenic accumulating flora can have to neighbouring fauna. Sharma and Shupe, 1977, reported rock squirrels (*Spermophilus varigatus*) in the vicinity of a smelting operation to have accumulated up to 13.3 ppm As in their livers from dining on vegetation containing 210 ppm As, although no indication of time lapse was given. This represents a considerable accumulation over the < 0.3 ppm normally detected in mammalian livers (NRC Arsenic Report, 1978).

While further research into food chain accumulation is called for, interim preventative measures, such as fencing, may have to be initiated for the exclusion of larger animals such as deer or moose.

1. Metal toxicity does not appear to be a growth factor at any of precious metal tailings investigated. Plant were able to grow without ill effect in the presence of soluble levels of arsenic ranging from 1.7-5.0 ppm and aluminum from 1.5-3.1 ppm on the Kerr Addison, Lake Shore Property, and Siscoe Metals tailings. Growth was likewise possible in the Delnite tailings, to which sandy topsoil had been added, in the presence of soluble levels of from 0.25-1.00 ppm zinc, 1.7-4.9 ppm copper, 50-350 ppm iron, 3.2-12.2 ppm arsenic, 2.6-8.0 ppm nickel, 18.2-31.2 ppm aluminum, and 0.4-1.1 ppm cobalt, given available calcium levels in the range 1,500-1,550 ppm which presumably reduced uptake into the roots of toxic elements.

2. The growth limiting factors at the Siscoe Metals tailing are physical in nature. They relate to the fine sandy texture of the fines which results in an unconsolidated surface and in excessive drainage losses of water and nutrients. The factors killing seedlings are principally wind erosion and drought. To reclaim this waste with vegetation, the tailing should be leveled, amended with organic matter to the rooting zone, and treated with a surface stabilizing agent, such as a spray-on organic mulch. With this preparation, the tailing could be seeded with a mix which includes the annual *Sorghum sudanense* (to increase surface stabilization and provide organic matter), the legumes *Coronilla varia* and *Lotus corniculatus*, and any of the grasses *Agropyron trachycaulum*, *Phleum pratense*, *Lolium perenne* (of the trial species); *Festuca arundinacea* (already colonizing along the perimeter); *Poa compressa* or *Agrostis grgantea* (showed good growth as transplants).

3. The predominant growth limiting factor at both the Kerr Addison and Lake Shore Property tailings is the chloride salinity. In addition, the compactness of the Kerr Addison fines requires the addition of fertilizer to promote healthy plant growth, with the 1120 kg/ha 7.7.7 application used in this study being most successful. Whereas the Lake Shore Property tailing has already been reclaimed through the natural colonization of halophytic species such as *Pucinellia distans*, *Atriplex patula* and *Hordeum jubatum*; these, in addition to *Chenopodium album* and *C. glaucum*, are readily encouraged to grow on the Kerr Addison tailing with fertilizer addition only. With fertilizer added, *Agropyron trachycaulum*, *Lolium perenne*, and *Sorghum sudanense* of the trial species and *Agrostis gigantea*, *Poa palustris*, and the legume Melilotus alba of the transplanted species showed excellent growth potential on the Kerr Addison fines.

4. As it is not deficient in calcium, the addition of a 5-10 cm layer of sandy topsoil to the Delnite waste effectively diluted the levels of soluble metals to the extent that several weedy species could grow. Species which colonized under these conditions include *Hordeum jubatum*, *Poa palustris*, *Poa compressa*, *Agrostis gigantea*, *Trifolium pratense*, in addition to several woody species, notably Salix spp. The agricultural strains were not as hardy. Only *Lolium perenne*, *Phleum pratense*, and *Sorghum sudanense* showed any potential, and then only in the presence of high fertilizer additions, i.e. 1, 120 kg/ha 7.7.7.

   As the topsoil layer was placed directly on the surface of the waste without a buffer zone between the two, the process of metal migration can be expected to eventually exclude the growth of the weedy species. However, a second sandy topsoil dressing, with a free-draining layer of gravel placed beneath, can be added and the cover restored by seeding to any of the colonizing species.

5. The use and/or encouragement of natural colonizing species shows excellent potential in the reclamation of precious metal tailings with vegetation in Northern Ontario. This practise has the potential to provide, with minimal amendment, a vegetative cover that is more productive and persistent than the use of agricultural species alone.

6. Neither *Lotus corniculatus*, *Coronilla varia*, nor *Phleum pratense* should be utilized in reclaiming wastes that show chloride salinity. Germination of *C. varia* seed is severely inhibited while *P. pratense* suffers reduced root growth. *L. corniculatus* appears to be inhibited at a later stage in the growth process.

7. Tailings in Northern Ontario should be seeded in the spring, rather than the fall, to ensure higher seed survival. The high mortality experienced with fall seeding could be due to overwintering stresses and to a direct toxic effect of imbibed salts.

8. The indigenous vegetation sampled from each of the tailings ponds had accumulated arsenic in excess of the levels normally found in plants. In general, higher accumulations were found in tailings containing higher total arsenic contents. This phenomenon poses a potential health threat to grazing wildlife, especially if this grazing is prolonged.

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THE GROWTH OF CATTAIL STANDS ON INACTIVE OR ABANDONED URANIUM MILL TAILINGS IN ONTARIO

M.M. Kalin

Institute for Environmental Studies

University of Toronto
Toronto, Ontario

ABSTRACT

Emergent macrophyte colonies of hybrids of *Typha latifolia* and *T. angustifolia* have established in wet areas on uranium mill tailings in Ontario. Plant and stand characteristics related to growth have been studied in 1981 and 1982. Seven tailings sites in Elliot Lake and three in the Bancroft area, have been selected to evaluate potential differences in growth between cattail stands on tailings and five stands on nontailing areas. Some characteristics such as plant height and leaf number did not differ between stands. Other characteristics such as plant density in the stand and the density of inflourescent bearing shoots were found to differ significantly between stands. Measurements of pH in the root region than on the surface. Differences could range from 0.5-2.0 pH values suggesting possible ameliorative effects on acidic drainage from pyritic tailings. Despite potential stress on the plants on the tailings, annual aerial biomass production for the established stands on the tailings was within the range reported for freshwater wetlands in this geographical region. The results suggest that cattail growth on uranium mill tailings is not impaired.

The abstract of the study on tailing sites in Elliot Lake and Bancroft summarizes the work which will be published by Environment Canada as a Technology Development Report, Environmental strategies Directorate presently. The title is "Long-Term Ecological Behaviour of Abandoned Uranium Mill Tailings" 2. "Growth Patterns of Idigenous Vegetation on Terrestrial and Semi-Aquatic Areas."

LONG-TERM BEHAVIOUR OF ABANDONED OR INACTIVE URANIUM MILL TAILINGS

M.M. Kalin

Semi-aquatic and terrestrial areas on abandoned or inactive uranium mill tailings in the Province of Ontario were studied in order to identify the growth characteristics of the naturally invading species dominating these areas. Semi-aquatic areas of tailings sites have been invaded by cattails. These species form wetland communities which vary in size, but all are essentially monucultures of _Typha latifolia_, _T. angustifolia_, or of the hybrids _T. glauca_. Sedges _Scripus cyperinus_ (wool-grass) and _Phragmites australis_ (reed-grass) are found in transition zones between the cattail stand and the dry section of the tailings site. The expansion of the cattail stands appear to be controlled by the hydrological conditions on the site, rather than the chemical characteristics of the tailings.

Cattail growth was studied for 2 years. Density in the stand, height growth, reproductive development and vegetative growth of the plants were studied in 13 cattail stands on the tailings and compared to five stands growing in nontailing environments. The results led to the conclusion that cattails, despite the extremely harsh environmental conditions on the tailings grow equally well there as on nontailing sites. The only indication of stress on the plants was the higher number of fruits on the acidic tailings site in the Elliot Lake area. However, the root zone of the cattails stands on the Elliot Lake and Bancroft tailings were found to be respectively less acidic and more acidic than the surface region. These observations do suggest that the roots have some control of their immediate environment's pH.

Annual above-ground biomass production reflected the reproductive state of the cattail stands. In vegetative stands there were more leaves, whereas in reproductive stands, there were more stems and fruits. The biomass quantities of the cattail stands on tailings were in the same range as those of the control stands and were related in all cases to the stand density. Decomposition coefficients, determined after one year of biomass was left to decay to litter, were found to be comparable to those in the control stands and to those reported in the literature. The total amount of litter in the tailing wetlands was determined

from litter collections. The anticipated quantity of litter in a cattail stand was calculated based on a model. Decomposition coefficients and annual biomass input for the stands on the tailings were used to derive long-term litter accumulation values. These values were compared to the measured quantity of litter in each stand. Approximately half of the cattail stands have reached a "steady state" on the tailings, where annual biomass input and decomposition have reached an equilibrium. The study of semi-aquatic areas on uranium mill tailings lead to the conclusion that the wetland communities are stable and growth will continue as long as the existing hydrological conditions prevail.

This work also determined the basic growth characteristics of Trembling aspen and White birch on uranium mill tailings. The terrestrial areas of uranium mill tailings, were Trembling aspens (Populus tremuloides) and White birch (Betula papyrifera) have colonized sections of inactive or abandoned tailings, exhibit diverse characteristics. Sites which have been revegetated with introduced grasses and legumes, such as Nordic in Elliot Lake and completely unammended sites in the Bancroft area (Auger and Bicroft Proper) both support tree stands. Trees have also colonized uranium tailings both where the surface was only stabilized with limestone (Stanrock in Elliot Lake) as well as at sites which were neutralized, fertilized and seeded once without further maintenance (Crotch in Elliot Lake). Regardless of the site condition and the time since amendment or abandonment, tree stands exhibited the same average height. Under all these site conditions, both Trembling aspen and Whitelbirch grow and exhibit a net height increase per annum. Net growth occurs in all size classes of trees and can range from 1 to 100 cm per year. The tree characteristics, however, reflect extremely poor site conditions, even on the sites which are fertilized annually. From the determinations of characteristics of selected stands in Bancroft and Elliot Lake, it can be inferred that the trees are stunted. Trees on nontailing sites had attained the same height as the trees on the tailings, but in fewer years. The tree form ie, the relationship between height, trunk and crown diameter and number of branches, however, did not deviate from that expected in regenerating forests.

The recruitment of the tree populations on tailings reflected the ecological characteristics of the species. Trembling aspen had root systems which suckered while seedling originated populations were less frequent than in White birch. Hence, the height class composition of the tree stands deferred between the species. White birch appears to exhibit more stable consistent growth than Trembling aspen on the tailings, though both species are shallow rooted.

Investigations of the root region of trees indicated large pH differences with several centimeters in depth. In locations were alkaline and acidic layers are not clearly separated, establishment of both aspen and birch is low, compared to locations with clearly separated pH strata.

Given the slow development of trees, the different recruitment methods of new trees in stands and the chemical characteristics of the root region on the tailings, development of these trees in the long-term cannot be determined. The long-term development of the semi-aquatic environments appear considerably more stable, as cattail growth was found to be extremely tolerant of the tailing conditions. The trees in the terrestrial environments, on the other hand, appear to be growing at their limits of ecological tolerance.

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ASPEN COLONIZATION OF AN UNAMENDED URANIUM MILL TAILINGS SITE NEAR BANCROFT, ONTARIO

C.L. Caza

Institute for Environmental Studies
University of Toronto
Toronto, Ontario

ABSTRACT

The study of plant populations colonizing waste sites can provide information on the potential of a plant species for reclamation under different management schemes and on the nature of a particular waste as a substrate for plant growth. Spatial variation in the biotic and abiotic environment was studied in an aspen population colonizing unamended uranium mill tailings site near Bancroft, Ontario. Vegetation and substrate characteristics were measured and principal components analysis was used to summarize physical, chemical, and biological differences within the site. Aspen distribution was correlated with substrate characteristics such as elevation, temperature, moisture, and nutrient content. Other parameters displayed large variation within the site but were not related to aspen distribution. Additional data were collected from nontailings (reference) aspen populations. There was no indication of differences in factors influencing distribution between uranium mill tailings and these substrates. The results of this study indicated that within a single tailings site there is significant variation in substrate characteristics related to aspen growth. The relationship between this variation and plant growth and distribution on the site has obvious implications for the development of management schemes.

The biology of trembling aspen was studied in detail in the pursuit of an M.Sc. degree at the Institute for Environmental Studies and the Department of Botany, University of Toronto. The abstract summarizes two years of field work on an unamended uranium tailings site near Bancroft, Ontario.

THE BIOLOGY OF *POPULUS TREMULOIDES* MICHX. ON AN UNAMENDED URANIUM MILL TAILINGS SITE NEAR BANCROFT, ONTARIO

C.L. Caza

ABSTRACT

To study the natural development of vegetation on uranium mill tailings, variation in the growth of *Populus tremuloides* Michx. was investigated on a tailings site near Bancroft, Ontario which displayed variability in its edaphic properties. Two aspen populations on unproductive natural soils (an acid, sandy pasture and a sandy outwash plain) were also studied for comparisons between aspen growth on poor natural substrates and the mining wastes.

Measurements of relative growth rates and expressions of tree form were related to age and density distributions and were compared for differences within and among the three study sites. The potential for seedling establishment was investigated by field and laboratory studies of seed germination and early seedling survival. The characteristics of aspen clones on the tailings were described and the importance of parental root connections to ramet growth was compared in tailings and nontailings populations.

Relative growth rates were low on all sites and substrate characteristics indicated that both the tailings and the natural substrates were poor for aspen growth. Despite low growth, however, there were significant differences among sites in growth rates and the expression of tree form. Generally, growth rates were higher on the nontailings sites but there were differences in the growth of very small trees (less than 50 cm) and larger trees. Very small trees showed better growth on dry, exposed areas of the tailings site than on the nontailings substrates. There were large differences in the age profiles of aspens among areas on the same site, but there were no consistent relationships between tree age and growth.

The physical, chemical, and biological characteristics of the tailings were summarized by principal components analysis and the relationships among PCA factors were described.

Differences in the growth of aspens on the tailings were associated with variation in the biological, chemical, and physical characteristics of the site. The results of this study indicate that, although the growth of aspens on unamended tailings is poor, the aspen population will be maintained because conditions are favourable for both seedling establishment and sucker production. As changes in edaphic and ecological conditions occur very slowly in these environments, this population may be expected to persist on the site for some time.

CHOOSING BETWEEN METAL-TOLERANT *DESCHAMPSIA CAESPITOSA* AND AGRONOMIC GRASSES IN THE REVEGETATION OF TOXIC, METALLIFEROUS TAILINGS IN THE YUKON TERRITORY

by

D. Blundon and K. Winterhalder
Biology Department, Laurentian University,
Sudbury, Ontario, P3E 2C6

ABSTRACT

Silver mine tailings at Elsa are circumneutral, high in lead, zinc, and cadmium, and show a textural and moisture gradient. Over a period of thirty years, no native plants have successfully invaded the tailings, except in water-saturated areas.

Seeds of *Deschampsia caespitosa* from metal-contaminated sites in the Sudbury area, Ontario, show reduced germination and very poor survival on tailings, even when fertilized and given adequate moisture. However, limestone application improves germination and survival. Once established, progressive loss of vigour occurs, but plants survive up to three years, and can renew growth when fertilized. Agronomic grasses also survive up to three years in a state of reduced vigour but do not renew growth without regular fertilization.

We conclude that the establishment of agronomic grasses is the simplest method of revegetating these tailings, provided that a high maintenance approach is used. Although *D. caespitosa* performs poorly under a no-maintenance regime, its ability to survive in a state of low vigour on potentially toxic tailings could make it a valuable seed mixture component where maintenance is likely to be irregular.

INTRODUCTION

The objective of this study was to examine the potential of multiple metal-tolerant *Deschampsia caespitosa* from the Sudbury area and agronomic grasses in the revegetation of toxic metalliferous tailings at Elsa, Yukon.

Only a few short term revegetation studies on metalliferous mine spoils have been carried out in the Yukon.

Kuja and Hutchinson (1979) screened several native species, including *Deschampsia caespitosa* from the Sudbury region, Ontario, on a number of Yukon tailings. They showed that these native species could be an economical alternative to commercial species, which are not acid or metal tolerant and have much higher nutrient requirements. They suggested that the use of amendments and often expensive management might then be minimized.

D. caespitosa has advantages as a potential revegetation candidate on Yukon tailings. It is able to colonize acid metal-contaminated barren areas in the Sudbury region (Amiro and Courtin, 1981) and it is tolerant to such metals as lead and zinc (Cox and Hutchinson, 1979). Seed of *D. caespitosa* collected from the southern Yukon proved to be very successful in revegetating disturbed terrain along the Dempster Highway (Vaartnou and Sons Enterprises Ltd., 1982). Kuja (1980) found that seedlings of *D. caespitosa*, from acid metal contaminated soils in the Sudbury area, grew better on unamended old weathered tailings from Elsa, Yukon than any other native species tested under greenhouse conditions.

A disadvantage of *D. caespitosa* may be that permanent ground moisture is a limiting factor governing its distribution (Lawrence, 1945). However, in the southern Yukon, *D. caespitosa* has been found in a burn area that is probably one of the driest parts of the Yukon (Rostad et al. 1977).

As for the revegetation potential of agronomic grasses, Bayne (1975), found that *Agropyron trachycaulum*, *Phleum pratense* and *Festuca rubra* did best on circumneutral metal contaminated tailings in the southern Yukon with the addition of fertilizer. Vaartnou and Sons Enterprises Ltd., (1982), tested the agronomics *Bromus inermis*, *Festuca rubra*, *Agropyron pauciflorum* and *A. cristatum* on disturbed terrain along the Dempster Highway (central Yukon) and found that they performed poorly, suffering from large over-wintering losses. Bliss and Wein (1972), found that the agronomic grasses *Festuca rubra*, *Poa pratensis*, *P. compressa*, *Phleum alpinum* and *Alopecurus pratense* gave best results in establishment and winter survival on disturbed sites in the Mackenzie Delta, N.W.T.

Peterson and Peterson (1977), after summarizing the published information on revegetation techniques that could be applied to the Yukon and Northwest Territories, recommended the use of mixtures of native and agronomic species that would be self-regulating.

MATERIALS AND METHODS

STUDY SITE

Elsa townsite is located on the north slope of Galena Hill in the central Yukon approximately 459 km north of Whitehorse. The townsite is owned and operated by United Keno Hill Mines Ltd. producing silver, lead, zinc and cadmium concentrate. The mill discharges roughly 63,500 tons of metalliferous tailings each year which are deposited as a slurry in a holding pond below the townsite. The present mill has been operating fairly regularly since 1949, producing enough tailings to cover approximately 84 ha. of land.

ENVIRONMENTAL PARAMETERS

Precipitation on the tailings was recorded daily from a Taylor clear-vu rain gauge secured at ground level.

Samples were collected from Elsa tailings for analysis of texture (Canada Department of Agriculture, 1970), moisture content (Allen et al. 1974), and pH (Richards, 1954 as given in Jackson, 1958). Total extractable, NH_4OAc extractable and H_2O extractable cations were analysed by atomic absorption at the Elsa assay laboratory (Perkin-Elmer Corporation, 1971). The NH_4OAc extractant was modified to a pH of 6.5. Water extractable cations were determined by substituting water as the extractant. Phosphorus was determined by the molybdenum blue method (Allen et al. 1974) and total organic nitrogen by the semi-micro Kjeldahl digestion method (Allen et al. 1974).

It was observed that in many seeded, fertilized and limed areas plant cover was discontinuous. Adjacent bare and vegetated (root zone) tailings samples were collected for mineral analysis from such areas.

Plant samples were collected, washed in a .01% solution of triton X-100, rinsed in three changes of distilled water, separated into roots and shoots, oven dried, and kept for mineral analysis.

FIELD TRIALS

1974 AGRONOMIC FIELD TRIAL

In July, 1974, B. Ward and Dr. G.M. Courtin set up an experimental revegetation plot on the east area of the Elsa tailings to test the agronomic grasses *Poa pratensis*, *Alopecurus pratensis*, *Agrostis gigantea*, *Festuca rubrum* and *Phleum pratense*. Two inorganic fertilizer types (20-20-20 and 5-10-5 % NPK) and slaked lime ($Ca(OH)_2$) were applied in fifteen combinations. The fertilizer: lime treatment ratios for each fertilizer were: 1:1, 1:0.5, 1:0, 0.5:1, 0.5:0.5 and 0.5:0 (1 = 224 g/m^2 and 0.5 = 112 g/m^2). Two levels of lime only (1 and 0.5) and one control (0) made up the remaining three treatments. The plots ($2.3m^2$) were prepared by raking in each treatment and then planting the seed mix at a rate of 4.5 g/m^2. Each species contributed an equal weight of seed.

In early June, 1976, two years after planting, a spring maintenance application of fertilizer (13-16-10 % NPK) and pulverized limestone ($CaCO_3$) was tested on a plot (initial application of 224 g/m^2 each of 20-20-20 % NPK fertilizer and lime) with an even cover of plants. The plot was randomly divided into four equal sections, each receiving a separate treatment. The treatments were as follows: 112 g/m^2 each of fertilizer and $CaCO_3$, 112 g/m^2 of fertilizer only, 112 g/m^2 of $CaCO_3$ only and a control.

In late June, 1976, an early summer maintenance application of 112 g/m^2 each of fertilizer (13-16-10 % NPK) and pulverized limestone was applied to the surviving 1974 agronomic plots.

1975 *DESCHAMPSIA CAESPITOSA* FIELD TRAIL

In July, 1975, Dr. G.M. Courtin set up an experimental plot on the east area of the tailings to test the agronomic grasses *Poa compressa*, *Agropyron cristatum*, *Elymus giganteus*, the legume *Lotus corniculatus* and the native grasses *Agrostis scabra*, *Deschampsia flexuosa* and *D. caespitosa* collected by K. Winterhalder from acid metal-contaminated soils in the Sudbury region. Each species was tested separately on two levels of fertilizer (20-20-20 % NPK) and lime ($Ca(OH)_2$). The treatments were as follows: 224 g/m^2 each of fertilizer and lime and 112 g/m^2 each of fertilizer and lime. The latter treatment was replicated twice. Each plot was prepared as described in the previous trial.

AGRONOMIC AND *DESCHAMPSIA CAESPITOSA* FIELD TRIAL

A late summer planting (August 15, 1965), on the west area of the tailings, of the agronomic grasses *Poa compressa*, *Agrostis gigantea*, *Alopecurus pratensis* and *Festuca rubra* and the Sudbury native grass *D. caespitosa* were tested as a seed mix with a variety of fertilizer (13-16-10 % NPK) and pulverized limestone combinations. The fertilizer: limestone treatment ratios were as follows: 1:1, 1:0.5, 1:0, 0.5:1, 0.5:0.5, 0.25:1, 0.25:0.5, 0:1 and control (1 = 224 g/m^2, 0.5 = 112 g/m^2, 0.25 = 56 g/m^2 and control = 0). Each treatment was replicated three times and each plot ($3m^2$) was prepared as described for the previous trial. Seed was sown at a rate of 4.5 g/m^2, each species contributing to the seed mix on an equal weight basis.

SUDBURY NATIVE PLANT FIELD TRIAL

The native grasses *Agrostis gigantea*, *A. scabra*, *Deschampsia flexuosa* and *D. caespitosa* from acid metal-contaminated soils of the Sudbury region were tested in a late summer (August 15, 1976) planting on the west area of the tailings. Adjacent $3m^2$ plots, one for each species, were treated with 224 g/m^2 each of fertilizer (13-16-10 % NPK) and pulverized limestone. Each plot was prepared as described for previous trails and sown at a rate of 4.5 g/m^2.

PEAT AND SAWDUST AMENDMENT FIELD TRIALS

The agronomic seed mix of *Poa pratensis*, *P. compressa*, *Alopecurus pratensis*, *Agrostis gigantea*, and *Festuca rubra* were tested on the west area of the tailings, in a late summer (August 18, 1976) planting using two locally available amendments, valley peat and sawmill sawdust. Four adjacent plots (2.4 m^2) were prepared as described for previous trails with 224 g/m^2 each of fertilizer (13-16-10 % NPK) and pulverized limestone. Approximately 2 kg/m^2 of peat or sawdust were incorporated into adjacent plots and seeded at a rate of 4.5 g/m^2.

In early June, 1978, a spring maintenance application of 112 g/m^2 each of urea fertilizer (46-0-0 % NPK), superphosphate fertilizer (0-18-0 % NPK) and pulverized limestone were added to all the plots.

Percent cover, density (# plants/plot) and average leaf height (cm) were measured for each plot of all the field trials.

In early September, 1981, a visit was made to the Elsa tailings site, A visual observation of the 1974 agronomic and Deschampsia caespitosa plots were made. Several plants, from each plot were removed with their tailings intact, brought back, and kept under greenhouse conditions.

POT EXPERIMENTS

AGRONOMIC SCREENING EXPERIMENT

A pot screening trial was carried out at Elsa in the summer of 1976. The objective of this trial was to test the response of the agronomic grasses, Poa pratensis, P. compressa, Alopecurus pratensis, Agrostis gigantea and Festuca rubra to various levels of fertilizer (13-16-10 % NPK) and/or pulverized limestone added to Elsa tailings.

A greenhouse was constructed of clear plastic sheeting and framed with 2x4" lumber. The top was removed during the day to allow access and exposure to full sunlight and closed at night to guard against frost.

Bulk composite surface samples were collected from the east area of the Elsa tailings. One hundred and eighty 10 cm plastic pots were prepared by placing Whatman #1 filter paper disks in the bottom of each pot to allow for free drainage and retention of the tailings. The twelve fertilizer: limestone treatment ratios were as follows: 1:1, 1:0.5, 1:0.25, 0.5:1, 0.5:0.5, 0.5:0.25, 0.5:0, 0:1, 0:0.5, 0:0.25 and control (1 = 224 g/m^2, 0.5 = 112 g/m^2, 0.25 = 56 g/m^2 and control = 0). The treatments were assigned to the appropriate pot and mixed into the tailings. Sufficient seed to cover the surface of each pot was planted. Each pot was watered 2 to 3 times per week. Seed was planted on June 22, germination (# seedlings/pot) was measured two weeks later and % cover, density (# plants/pot) and average leaf height were measured after nine weeks.

DESCHAMPSIA CAESPITOSA POT EXPERIMENT

The technique of serial dilution of Elsa tailings with commercial silica sand (Indusmin #70) was used to determine the extent to which Elsa tailings inhibit germination and survival of D. caespitosa (Hogan et al. 1977).

Bulk composite surface tailings collected from Elsa in 1976 and stored until 1982 were used for the experiment. Viable seed of D. caespitosa from acid metal-contaminated soils in the Sudbury region were used. Eight treatments consisting of the following percentages of tailings were used: 100, 50, 25, 12.5, 6.25, 3.12, 1.56 and 0. Each treatment was replicated five times. Forty 10 cm plastic pots were prepared by placing Whatman #1 filter paper disks and fine mesh nylon in the bottom of each pot to ensure free drainage and retention of the tailings: sand mixture. The pots were placed in an environmentally controlled chamber with approximately 100 seeds planted in each pot. Each pot was subirrigated from an outer container with 1/4 strength Hoaglands nutrient solution and allowed to drain every two days.

During the initial two week period, emerging seedlings were counted to determine the germination rate for each pot. After the third week, all but ten plants were removed from each pot. After six weeks, all plants were harvested, oven dried at 65°C and weighed.

The results from both pot experiments were analysed using one or two-way analysis of variance ($p = 0.05$) where appropriate (Sokal and Rohlf, 1969).

The pH of the bulk tailings and the pots at the end of the experiment were recorded, as described earlier.

RESULTS AND DISCUSSION

TAILINGS

The climate of Elsa is dry continental characterized by low precipitation and a wide temperature range. During the study period, 1976 to 1978, summer precipitation varied considerably from month to month and year to year. August precipitation was consistently lower than the 14 year mean for that month (Table 1). Very low summer precipitation (136 - 165 mm) is typical of most areas in the Yukon (Rostad et al. 1977).

Table 1. Comparison of monthly summer precipitation (1976 to 1978) and mean monthly precipitation (1950 to 1963) for Elsa, Yukon.

Month	Precipitation (mm)			
	1976	1977	1978	1950-1963 *
May	--	--	9.6	23.4
June	--	41.3	57.4	32.3
July	76.3	34.5	76.0	64.3
August	11.0	9.9	18.7	63.5
September	--	30.6	--	38.6

* Data from Green, 1971.

Approximately 75% of the tailings area is either active (periodically inundated with mill slurry) or water soaked from natural seepage. The dry inactive tailings are confined to the west and south sections of the tailings area. They are located on higher ground and are, thus, less susceptible to mill discharge and natural seepage.

Over a period of thirty years, no native plants have successfully invaded the tailings except in water-saturated areas, organically enriched areas such as on old tree stumps, and areas where the tailings are only a few centimetres thick. Of special interest is the successful invasion of Salix spp. and Carex aquatilis on a shallow layer of local gravel which had been spread on the tailings in 1976. This suggests that moisture is limiting on Elsa tailings.

The tailings comprise a mozaic of minerals, being predominantly composed of quartz (51 - 78%) and smaller quantities of quartzite, graphitic schist, siderite ($FeCO_3$), galena (PbS), pyrite (FeS_2), limonite ($FeO(OH.nH_2)$), pyrolusite (MnO_2), jarosite ($KFe_2(SO_4)_2(OH_6)$), sphalerite (ZnS), anglesite ($PbSO_4$) and $ZnSO_4$.

Old dry inactive tailings are coarse in texture, 3% silt and clay (Table 2) compared to freshly discharged mill tailings which are high in silt and clay (36%). "Slimes", fine textured wet tailings, are always encountered down slope of coarser, dry tailings. A white surface crust was prevalent on the coarse tailings during dry periods which occurred throughout the summer. This type of saline crust is prevalent on tailings in dry climates which contain both pyrite and calcareous material (Bradshaw and Chadwick, 1980).

Table 2. Physical and chemical properties of Elsa tailings (Mean ± SD).

Particle size analysis (%)[a]	
Gravel >2 mm	0.25
Very coarse sand 2 - 1.0	1.5
Coarse sand 1 - 0.5	1.0
Medium sand 0.5 - 0.25	15.25
Fine sand 0.25 - 0.10	27.5
Very fine sand 0.10 - 0.05	52.25
Silt and clay <0.05	3.0
Bulk density (g/cm^3)[b]	1.28 ± 0.12
Particle density (g/cm^3)[b]	1.56 ± 0.11
Pore space (%)	19
Moisture (%)[c]	5.67 ± 3.08
Moisture holding capacity (%)[g]	21
pH (overall)[d]	6.73 ± 0.64
pH (east area)[e]	6.75 ± 0.56
pH (west area)[f]	5.89 ± 0.44
Conductivity (mmhos at 18°C)[g]	3.3 ± 0.2
Organic matter (%)[g]	0.58 ± 0.04

[a] n = 1
[b] n = 3
[c] Moisture (%) after 1mm of rainfall. n = 9
[d] Courtin, 1976. n = 11
[e] n = 6
[f] n = 9
[g] Kuja, 1980. n = 2

Commonly in August as little as 1 mm of rain would fall on the tailings at a time, resulting in a surface moisture content of 5.67% (Table 2). The moisture content of the tailings improves with depth (22% at 5 cm) and the presence of vegetation (29%), values which are comparable to the moisture holding capacity (21%) of the tailings. This suggests that subsurface moisture is available and the presence of vegetation improves surface moisture conditions.

Wet patches are noticeable on the tailings after a rain and appear to be related to the presence of slimes. After 1 mm of rain wet patches have a surface moisture content of 10%, and adjacent drier areas (white crust areas) have as little as 1% moisture. Such a moisture gradient may impose serious problems to the establishment of a continuous vegetation cover on the tailings.

The mean overall pH was circumneutral (6.73) but can be acidic (5.35) on older, dry tailings. The older west area of the tailings had a lower pH than the east section (Table 2). This pH differential is probably a result of oxidation, which is common on exposed, weathered tailings and may impose another serious problem to vegetation by increasing the solubility of the metals present in the tailings (Gemmell, 1977).

The electrical conductivity (Table 2) is in the normal soil range (Bohn et al. 1979) and salinity is not considered to be a serious problem.

Organic matter content is very low (Table 2), typical of tailings where the milling process provides no source of organic matter prior to deposition (Murray, 1977).

Elsa tailings contain high potentially toxic metal levels and low levels of some essential soil nutrients, typical of abandoned metalliferous mine spoils (Goodman et al. 1973, Bradshaw and McNeilly, 1981). An examination of Table 3 shows the high extractable levels of Zn, Cd, Pb, Mn and Fe and low levels of Mg, Ca, P, K and N (Lindsay, 1979).

A mineral analysis of Poa pratensis and Deschampsia caespitosa growing on Elsa tailings showed that both plants had accumulated excess levels of zinc, cadmium, lead and manganese (Bohn et al. 1979). Water extractable root zone levels of D. caespitosa were consistantly higher than those of P. pratensis.

Table 3. Mean concentration (± SD) of selected elements in Elsa tailings (n = 43).

	Total Extractable (µg/g ± SD)	NH_4OAc Extractable (µg/g ± SD)	H_2O Extractable (µg/g ± SD)
Cd	163 ± 152	58 ± 92	14 ± 15
Zn	9800 ± 6800	2600 ± 5800	1193 ± 4134
Pb	11400 ± 4900	5800 ± 3500	27 ± 15
Mn	50300 ± 18100	3023 ± 12826	948 ± 2112
Fe	136900 ± 46700	130 ± 148	43 ± 25
Ni	51 ± 20	10 ± 9	< 1
Ca	183 ± 59	21 ± 12	< 1
Co	61 ± 14	10 ± 6	< 1
Sb	427 ± 151	28 ± 11	22 ± 6
As	1889 ± 1085	11 ± 5	< 1
U	86 ± 23[c]	---	---
Na	235 ± 18[c]	---	229 ± 75[b]
AL	7400 ± 2200[c]	---	---
Cl	ND[c]	---	---
S	51000[c]	---	---
SO_4	4600 ± 100[c]	---	---
Mg	1119 ± 179	191 ± 38	173 ± 39
Ca	3495 ± 1977	1787 ± 1062	901 ± 824
K	2159 ± 649	191 ± 27	151 ± 41
P	34 ± 29	---	---
N	540 ± 760[c] (total nitrogen)		
N	ND[a] (kjeldahl nitrogen)		

[a] Non-detectable
[b] n = 13
[c] Kuja, 1980. (n = 2)

Total and water extractable metal levels were consistently lower in the root zone of vegetated tailings than in adjacent bare tailings (Table 4). These tailings were planted with agronomic grasses and treated with 224 g/m^2 each of fertilizer (13-16-10 % NPK) and pulverized limestone. The lack of vegetation in this barren area may be due to the presence of the higher metal levels creating a phytotoxic situation.

Table 4. Mean concentration of selected elements in adjacent bare and vegetated (root zone) areas of tailings planted with agronomic grasses and treated with 224 g/m^2 each of fertilizer (13-16-10 % NPK) and pulverized limestone (n=5).

Element	Tailings			
	Bare		Vegetated	
	Total Extractable µg/g ± SD	H_2O Extractable µg/g ± SD	Total Extractable µg/g ± SD	H_2O Extractable µg/g ± SD
Cd	140 ± 58	15 ± 13	128 ± 11	10 ± 10
Zn	5555 ± 1843	289 ± 212	5128 ± 807	219 ± 221
Pb	7260 ± 2032	29 ± 48	5792 ± 1324	5 ± 2
Mn	33228 ± 3482	1062 ± 1629	32440 ± 1061	924 ± 1224
Na		250 ± 76		168 ± 22
Ca	8144 ± 3872	4692 ± 2630	8600 ± 1857	4768 ± 1722
K	198 ± 66		86 ± 18	
N*	680 ± 249		620 ± 179	

*Kjeldahl nitrogen

1974 AGRONOMIC FIELD TRIAL

The 1976 spring evaluation of the 1974 agronomic plots showed that growth was generally poor and rapidly deteriorating (Table 5). The spring maintenance test of fertilizer (13-16-10 % NPK) and/or pulverized limestone showed a rapid response (% cover of green leaves) to 112 g/m^2 each of 13-16-10 % NPK and limestone and to 112 g/m^2 of 13-16-10 % NPK only. Response was poor to limestone only and the control (no fertilizer or limestone). As a result of this experiment, 112 g/m^2 each of 13-16-10 % NPK and $CaCO_3$ were added to the remaining surviving plots in late June. The response was good, showing an increase in cover (%), density and leaf height (Table 5, fall 1976). No maintenance application of fertilizer or limestone was provided in 1977. In that year, a decline in % cover and leaf height occurred in four of the six plots (Table 5). In the spring of 1978, a maintenance application of 112 g/m^2 each of urea fertilizer (46-0-5 % NPK), super phosphate fertilizer (0-18-0 % NPK) and pulverized limestone produced a good response showing the best cover (%), density, and leaf height for all the plots.

Only the plots with an initial application of fertilizer survived and only one plot that did not have an initial application of lime ($Ca(OH)_2$) survived. Of the six initial

Table 5. Mean (± SD) cover (%), density (# plants/plot) and average leaf height (cm) of the surviving 1974 agronomic grass plot, from 1976 to 1978. (Lime = $Ca(OH)_2$, numbers refer to % NPK of fertilizer used, 1 = 224 g/m^2, 1/2 = 112 g/m^2, control = 0 g/m^2) n = 2.

Year		1 20-20-20 1 Lime	1/2 20-20-20 1 Lime	1/2 20-20-20 1/2 Lime	1/2 20-20-20 0 Lime	1 5-10-5 1 Lime	1/2 5-10-5 1 Lime	Control
1976	Cover	24 ± 1	2 ± 0	2 ± 1	2 ± 1	1 ± 0	3 ± 3	
(Spring)	Density	32 ± 4	3 ± 1	4 ± 1	1 ± 1	1 ± 0	2 ± 1	0
	Height	5 ± 1	3 ± 0	3 ± 1	4 ± 2	3 ± 0	4 ± 6	
1976[a]	Cover	29 ± 5	8 ± 10	7 ± 3	5 ± 6	3 ± 1	8 ± 10	
(Fall)	Density	22 ± 6	8 ± 7	11 ± 1	6 ± 8	5 ± 3	9 ± 12	0
	Height	19 ± 4	8 ± 0	13 ± 6	6 ± 2	18 ± 10	22 ± 3	
1977	Cover	10 ± 0	2 ± 1	3 ± 3	4 ± 4	5 ± 3	11 ± 13	
(Fall)	Density	41 ± 0	19 ± 15	4 ± 3	16 ± 19	19 ± 6	26 ± 34	0
	Height	15 ± 9	7 ± 3	8 ± 3	9 ± 4	10 ± 7	12 ± 6	
1978[b]	Cover	42 ± 3	11 ± 13	6 ± 6	13 ± 7	18 ± 17	30 ± 42	
(Fall)	Density	54 ± 7	11 ± 12	6 ± 6	15 ± 19	20 ± 0	25 ± 42	0
	Height	13 ± 6	13 ± 2	36 ± 35	10 ± 2	19 ± 9	22 ± 3	

[a] Summer maintenance application of 112 g/m^2 each of fertilizer (13-16-10 % NPK) and pulverized limestone.

[b] Spring maintenance application of 112 g/m^2 each of urea (46-0-0 % NPK) and superphosphate (0-18-0 % NPK) fertilizers and pulverized limestone.

plots which received the high (%) NPK fertilizer (20-20-20), four survived. Of the six initial plots that received the lower (%) NPK fertilizer (5-10-5), only two survived. No plots survived that received lime only or no lime and fertilizer.

Of the five agronomics planted in 1974, only *Poa pratensis* and *Agrostis gigantea* survived until 1978. *P. pratensis* did the best, surviving in all the remaining plots. *A. gigantea* survived in four of the plots. *Alopecurus pratensis* survived in several plots until 1977, but died out by 1978 (Table 6).

On close examination, the 1981 observation of the agronomic plots showed that several shoots were still green. When transplanted to the greenhouse, still in the tailings medium, these grasses did not renew growth with the addition of nutrients, suggesting these plants were not going to survive another year with or without the addition of fertilizer on Elsa tailings.

Crowder *et al*. (1982) have found that of the original agronomic seed mixtures sown from 1958 to 1962 on tailings at Copper Cliff, Ontario, *Poa pratensis* and *Agrostis gigantea* have become dominant. They found that roots of *P. pratensis* accumulated Cu, Ni and Fe and likened this to a characteristic of metal-tolerant strains of grass and cereals. It has also been shown that it is possible to select for metal tolerance in commercial seed of *Agrostis tenuis* (1 in 7,000 plants) in one generation after planting on copper-mine soil (Antonovics *et al*., 1971). Possibly, such a selection exists for *Poa pratensis* and a few plants are able to survive, albeit in a state of reduced vigour, on metal-contaminated Elsa tailings.

1975 *DESCHAMPSIA CAESPITOSA* FIELD TRIAL

The 1976 evaluation of the 1975 planting showed that the agronomic grasses *Poa compressa*, *Agropyron cristatum*, *Elymus giganteus*, and the legume *Lotus corniculatus* and the Sudbury native grasses *Agrostis scabra*, *Deschampsia flexuosa* were all doing poorly, with only a few individuals surviving. *D. caespitosa* was much more successful, achieving up to 90% cover (Table 7). Three years after planting (1978), however, *D. caespitosa* showed signs of continued loss of vigour and was fertilized with 112 g/m^2 each of urea (46-0-5 % NPK), super phosphate (0-18-0 % NPK) and pulverized limestone. Recovery was evident in two of three plots, but continued to decrease in the plot that had initially done so well (90% cover, Table 7).

Table 6. Mean (± SD) density (#plants/plot) of the surviving grasses of the 1974 agronomic grass plots, from 1977 to 1978 (Lime = $Ca(OH)_2$, numbers refer to % NPK of fertilizer used, 1 = 224 g/m^2, 1/2 = 112 g/m^2, control = 0 g/m^2) n=2.

Treatment	1977 Poa pratensis	1977 Agrostis gigantea	1977 Alopecurus pratensis	1978 Poa pratensis	1978 Agrostis gigantea	1978 Alopecurus pratensis
1 20-20-20 1 lime	30 ± 14	0	10 ± 13	54 ± 7	0	0
1/2 20-20-20 1 lime	19 ± 15	0	0	10 ± 12	<1	0
1/2 20-20-20 1/2 lime	4 ± 3	0	0	6 ± 6	0	0
1/2 20-20-20 0 lime	13 ± 17	0	0	10 ± 13	<1	0
1 5-10-5 1 lime	9 ± 6	10 ± 0	<1	6 ± 9	13 ± 9	0
1/2 5-10-5 1 lime	11 ± 6	6 ± 6	4 ± 6	10 ± 14	15 ± 20	0
Control	0	0	0	0	0	0

Of the remaining plots, only a few plants of D. flexuosa and A. scabra survived.

By 1978, seven tussucks of D. caespitosa were found alive outside the plot perimeter, suggesting that the originally planted seed was either washed out of the plot or that new seed was produced and germinated on untreated tailings.

The 1981 observation of the D. caespitosa plot and greenhouse transplants revealed that plants were still alive, in a state of reduced vigour, and continued to grow with the addition of nutrients. D. caespitosa like the agronomic grasses Poa pratensis and Agrostis gigantea is able to survive up to three years on Elsa tailings without the addition of fertilizer. D. caespitosa appears to be more resilient on Elsa tailings than the agronomic grasses, which do not renew growth after 3 years, making it a valuable revegetation species where maintenance fertilizer additions are likely to be infrequent (up to 3 years apart).

Table 7. % Cover, density (# plants/plot) and average leaf height (cm) of the 1975 Deschampsia caespitosa plots, from 1976 to 1978 (lime = $Ca(OH)_2$, numbers refer to % NPK of fertilizer used, 1 = 224 g/m^2 and 1/2 = 112 g/m^2).

Year		1 20-20-20 1 Lime	1/2 20-20-20 1/2 Lime	
1976	Cover	30	25	90
	Density	52	25	65
	Height	30	15	50
1977	Cover	7	9	40
	Density	12	10	30
	Height	15	13	23
1978+	Cover	35	30	15
	Density	20	30	20
	Height	12	12	15

+ Spring maintenance application of 112 g/m^2 each of urea (46-0-0 % NPK) and super phosphate (0-18-0 % NPK) fertilizers and pulverized limestone.

AGRONOMIC AND DESCHAMPSIA CAESPITOSA FIELD TRIAL

The results from this plot were very poor for both growing seasons (Table 8). Best growth for both years was acheived on the high fertilizer-only treatment. No growth occurred on the limestone-only and control plots. The poor results (4-5 % cover) were indicative of many attempts made to establish vegetation on the slightly more acidic west area of the tailings (Table 2).

From Table 9 it can be seen that D. caespitosa did not germinate either year. Even though the seed viability of D. caespitosa was not tested, seed from the same lot did germinate in another plot (Sudbury native plant trial). All the agronomics tested survived until 1977, but only Agrostis gigantea and Festuca rubra survived until 1978.

Table 8. Mean (±S.D.) cover, density and average leaf height of the agronomic grass mix and Deschampsia caespitosa plot (planted in 1976) from 1977 to 1978.

(L = pulverized limestone, F = fertilizer (13-16-10 % NPK), 1 = 224 g/m^2, 1/2 = 112 g/m^2, 1/4 = 56 g/m^2, Control = 0 g/m^2).

Treatment F/L	1977 Cover (%)	1977 Density (#/Plot)	1977 Height (cm)	1978 Cover (%)	1978 Density (#/Plot)	1978 Height (cm)
1F 1L	1.7 ± 1.1	21.7 ± 14.4	8.0 ± 5.3	1.3 ± 1.5	3.3 ± 4.2	7.0 ± 7.5
1F 1/2L	4.7 ± 6.0	26.7 ± 12.6	10.3 ± 2.3	<1	1.0 ± 1.7	2.0 ± 3.5
1F 0L	5.3 ± 8.4	18.3 ± 16.1	7.0 ± 7.5	4.3 ± 6.6	7.0 ± 7.5	8.0 ± 7.5
1/2F 1L	1.5 ± 0.9	26.7 ± 12.6	4.3 ± 2.1	1	1.0 ± 1.7	3.0 ± 5.2
1/2F 1/2L	1.3 ± 0.6	15.0 ± 13.0	7.0 ± 2.6	2.0 ± 1.7	10.0 ±10.0	8.0 ± 7.5
1/4F 1L	1.0 ± 0	16.7 ± 5.8	4.3 ± 3.5	0	0	0
1/4F 1/2L	4.7 ± 6.0	26.7 ± 12.6	10.3 ± 2.3	1.0 ± 1.7	6.7 ±11.5	3.0 ± 5.2
LF 1L	0	0	0	<1	1.7 ± 2.9	2.0 ± 3.5
CONTROL	0	0	0	0	0	0

Table 9. Number of plants of each species from the agronomic grass mix plus Deschampsia caespitosa plot (for all treatments) from 1977 to 1978.

Species	1977	1978
Agrostis gigantea	180	42
Festuca rubra	110	43
Alopecurus pratensis	65	0
Poa compressa	50	0
Deschampsia caespitosa	0	0

SUDBURY NATIVE PLANT FIELD TRIAL

The 1977 evaluation of the Sudbury native grasses showed Agrostis gigantea did the best, followed by Deschampsia caespitosa and A. scabra. By 1978 none of the grasses had survived. D. flexuosa did not germinate either year (Table 10). D. flexuosa and A. scabra also did poorly in a previously described experiment, indicating they are very poor candidates for revegetation of Elsa tailings.

It can be seen from this field trial and previous ones that *D. caespitosa* has difficulty germinating and surviving on Elsa tailings in comparison to the agronomic grasses, but once established *D. caespitosa* does as well.

Table 10. Cover, density and average leaf height of four Sudbury native grasses, planted on Elsa tailings in 1976, from 1977 to 1978.

	1977			1978		
Species	Cover (%)	Density (#/Plot)	Height (cm)	Cover (%)	Density (#/Plot)	Height (cm)
Agrostis scabra	5	2	8	0	0	0
Deschampsia flexuosa	0	0	0	0	0	0
A. gigantea	30	45	6	0	0	0
D. caespitosa	10	4	2	0	0	0

PEAT AND SAWDUST AMENDMENT FIELD TRIALS

The 1977 evaluation of the peat and sawdust plots showed that both amendments had a beneficial affect on the growth of the commercial grasses. Growth increased markedly from 1977 to 1978 on both amendments. Best cover was achieved on peat after three years (75%) versus 27% for sawdust. All the grasses germinated and survived until 1977 on both amendments. Only *Agrostis gigantea* and *Alopecurus pratensis* survived until 1978 on both amendments. *Poa pratensis* survived until 1978 on peat only (Table 11).

Table 11. Mean (±S.D.) cover (%), density (plants/plot) and average height (cm) of the commercial grass plots amended with local valley peat and mill sawdust (planted in 1976) from 1977 to 1978.

Year		Mill Sawdust	Valley Peat
1977	Cover	8.7 ± 8.8	40.0 ± 0
	Density	50.0 ± 7.1	85.0 ± 7.1
	Height	9.0 ± 1.4	13.0 ± 0
1978	Cover	27.5 ±17.7	75.0 ± 7.1
	Density	100.0 ± 0	200.0 ± 0
	Height	13.5 ± 2.1	25.5 ± 6.4

The addition of organic matter improves the moisture conditions in the tailings, reduces surface crust formation and thus allows for better germination and survival. Organic matter also has the ability to form stable chelate complexes with toxic metal cations, thereby reducing their availability and toxicity to plants in soil (Gemmell, 1977).

On the slightly more acid west area, as compared to the east area of the tailings, the establishment of vegetation was very difficult. As described in a previous trial (agronomic and Deschampsia caespitosa field trial) % cover was low (< 5%) which was indicative of many other attempts in the same area. The addition of mill sawdust, although producing a small cover (27%), still improved growth sufficiently over plots that did not contain sawdust. It was also readily available, being a waste product of the sawmill, making it a suitable amendment. Although peat was the better amendment its extraction from the valley was very destructive making it unusable in a large scale revegetation program. In isolated areas on the tailings which are especially difficult to revegetate peat could be used.

POT EXPERIMENTS

AGRONOMIC SCREENING EXPERIMENT

Germination of all the agronomic grasses tested was not significantly ($p = 0.05$) affected by the addition of fertilizer (13-16-10 % NPK) and/or pulverized limestone.

Growth (leaf height) of all the grasses was significantly ($p = 0.05$) affected by the addition of fertilizer. Poa compressa, Alopecurus pratensis and Agrostis gigantea growth was significantly ($p = 0.05$) affected by the addition of limestone whereas Poa pratensis and Festuca rubra were not. Only P. compressa growth was significantly ($p = 0.05$) affected by the interaction of limestone and fertilizer (Table 12). Clearly, fertilizer is essential for growth and limestone is not. The tailings are obviously deficient in the major nutrients (N, P, K) but not calcium.

Table 12. Analysis of variance ($p = 0.05$) of the agronomic grass pot experiment. Results are from growth responses (leaf height) to three levels (0, 1/2 and 1) each of fertilizer (13-16-10 % NPK) and/or pulverized limestone (0 = control, 1/2 = 112 g/m^2 and 1 = 224 g/m^2).

Species	Fertilizer	Limestone	Fertilizer/Limestone
Poa compressa	*	*	*
Poa pratensis	*	N.S.	N.S.
Festuca rubra	*	N.S.	N.S.
Alopecurus pratensis	*	N.S.	N.S.
Agrostis gigantea	*	*	N.S.

N.S. = Non-significant

F. rubra attained its best growth with the maximum addition of fertilizer (224 g/m^2) with no limestone, whereas, the other grasses grew best with the maximum addition of fertilizer plus limestone. In the latter case, the addition of limestone doubles the growth of these grasses over that which was obtained with the fertilizer alone. As previously described the results of the field trials show that Poa pratensis and Agrostis gigantea do the best on the tailings, especially with an initial application of both fertilizer and lime ($Ca(OH)_2$). The reason for this improved growth must be the increased calcium level and/or the increased pH that would occur. In field studies it was found that a similar application of limestone (224 g/m^2) raised the calcium concentration from 3495 μg/g to 8600 μg/G and the pH from 6.3 to 7.0. Both these increases could be important in suppressing the potential metal toxicity of the tailings. Calcium reduces the uptake of manganese, boron and zinc (Sutcliffe and Baker, 1974) and raising the pH by adding lime, lowers the soluble concentration of heavy metals resulting from the oxidation of sulfides (Nielson and Peterson, 1972).

DESCHAMPSIA CAESPITOSA POT EXPERIMENT

The germination of D. caespitosa varied significantly ($p = 0.05$) within tailings: silica sand treatments. Table 13 shows that germination was twice as high on pure silica sand than on pure tailings. A 45% reduction in germination occurred when 50% of the mixture was tailings. The addition of sand had a beneficial effect on germination, but only with a considerable dilution of the tailings (< 25% tailings). Gemmell (1975) reported a similar effect of improved germination with large dilutions of toxic chromate waste with sand. Cox (1979) reports that metal tolerant clones of D. caespitosa have incidentally increased the requirement for cadmium, zinc and lead for germination and post-germination survival on acid metal-contaminated Sudbury soil. However, seedling survival was reduced on the O'Donnell roast bed 'soil'. Elsa tailings appear to represent an even more toxic medium on which without an ameliorant such as sand or $CaCO_3$ survival is impossible.

Net shoot dry weight was significantly (p = 0.05) increased with successive dilutions of the tailings. A sharp decrease in shoot dry weight occurred with the addition of more than 12.5% tailings to the tailings:sand mixture. There was no survival of D. caespitosa on pure tailings (Table 13).

Table 13. Mean (± SD) germination and net shoot dry weight ($gx10^{-2}$) of Deschampsia caespitosa and pH in the tailings:sand dilution pot experiment.

g Tailings/ 100 g mixture	% Germination	Shoot Dry Weight	pH
0	58.0 ± 17.0	113.0 ± 13.2	8.9 ± 0.4
1.56	56.0 ± 14.4	103.0 ± 21.1	8.6 ± 0.3
3.12	56.4 ± 8.6	80.2 ± 25.4	8.1 ± 0.5
6.25	54.4 ± 10.0	58.6 ± 14.1	8.0 ± 0.4
12.5	44.6 ± 9.9	22.8 ± 6.8	6.9 ± 0.1
25	40.6 ± 4.9	14.6 ± 3.8	6.7 ± 0.1
50	30.4 ± 2.3	4.8 ± 1.3	6.5 ± 0.1
100	26.2 ± 3.5	0	6.4 ± 0.1

A significant (p = 0.05 difference in pH occurred within the tailings:sand dilution series. The pH dropped from alkaline (8.9) in pure silica sand to slightly acidic (6.4) in pure tailings. The increase in shoot growth with the increasing amounts of sand in the tailings:sand mixture also follows the increase in pH (Table 13). This suggests a decreased availability of metals with increasing pH (Nielson and Peterson, 1972) may also be occurring along with a dilution of the tailings with sand (Weston, 1965). A 50% reduction in shoot dry weight occurred at a tailings dilution of 6.25% and at a pH of 8.0. It is apparent that Elsa tailings are very toxic to D. caespitosa even under alkaline conditions (Simon, 1978).

A series of preliminary petri dish experiments were run to determine whether limestone and nutrient solution alone or in combination had an effect on the germination and survival of *D. caespitosa* on tailings. Limestone added to tailings increased germination and survival noticeably above tailings with no limestone added. The addition of only nutrient solution to the tailings also increased germination, but survival was poor. The addition of both limestone and nutrient solution increased germination and survival. pH increased with increasing additions of limestone (Table 14). Limestone has two confounded effects as described previously (provision of calcium and hydroxyl ions) and *D. caespitosa* apparently responds to one or both of these.

Table 14. % Germination (# seedlings emerged after 2 weeks) and % survival (# seedlings alive after 4 weeks) of *Deschampsia caespitosa* sown on Elsa tailings in petri dishes with increasing levels of $CaCO_3$, with and without nutrient solution.

	H_2O Only		Nutrient Solution		
$CaCO_3$	Germination	Survival	Germination	Survival	pH
0	23	2	44	7	6.2
1/2	45	22	30	18	7.6
1	54	26	46	28	7.5
2	36	18	50	27	7.8
4	44	35	56	54	7.7

In the previous pot experiment, agronomic grasses were found not to require limestone for survival on Elsa tailings (Table 12) which is in marked contrast to *D. caespitosa*. One difference between the agronomic grass and *D. caespitosa* pot experiments is the sampling location and age of the tailings. The tailings for the agronomic grass experiment were fresh and from the east area of the tailings which had a pH of 6.75 ± 0.56 (Table 2). The tailings for the *D. caespitosa* experiment had been stored for 6 years and had a pH of 5.92 ± 0.06 typical of the west area, which had been sampled as low as 5.40 ± 0.07 in two plots. This suggests that the tailings are marginally phytotoxic and the intensity of toxicity is dependant on the local pH, calcium concentration and metal content (Gemmell, 1977).

CONCLUSIONS

Silver mine tailings at Elsa, Yukon, are circumneutral, high in potentially toxic metals, nutrient poor, show a textural and moisture gradient and are prone to drought.

Attempts were made from 1974 to 1978 to revegetate these tailings with a variety of native grasses from acid metal-contaminated soils in the Sudbury, Ontario region, and with agronomic species using amendments commonly used in revegetation.

The results indicate that Deschampsia caespitosa was the only suitable native grass and Poa pratensis and Agrostis gigantea were the best agronomic grasses for revegetation. Legumes could not be established on the tailings.

All initial applications of 224 g/m^2 each of a high % NPK inorganic fertilizer (20-20-20) and slaked lime showed the best growth response. Growth is possible but poor on the tailings with an initial application of fertilized only.

Maintenance applications every two to three years of 112 g/m^2 each of the inorganic fertilizers urea (46-0-0 % NPK) plus superphosphate (0-18-0 % NPK) or 13-16-10 % NPK were necessary to sustain growth in native and agronomic grasses. It is questionable whether a limestone maintenance application is necessary. Under greenhouse conditions agronomic grasses do not require limestone additions to grow on Elsa tailings, but do double their growth when limestone is added with fertilizer at high rates (224 g/m^2). In contrast to the agronomic grasses, Deschampsia caespitosa requires limestone additions for early survival on Elsa tailings.

The addition of the organic amendments peat and sawdust markedly improve growth of the agronomics on Elsa tailings. The best cover of any agronomic plot was achieved with the addition of peat.

Early survival (first growing season) is a problem on the tailings because of the frequent dry periods which occur throughout the spring and summer. This could be especially limiting to the growth of Deschampsia caespitosa which is not drought tolerant.

Circumstantial evidence shows that metal tolerant Deschampsia caespitosa grows in tailings which have higher metal levels than areas where the agronomic grass Poa pratensis grows. Also, agronomic grasses grow in areas on the tailings which have lower metal levels than adjacent failed seeded areas. Possibly, metal tolerant Deschampsia caespitosa is able to grow in tailings with a higher metal content than those which the agronomic grass Poa pratensis grow on.

Once established, progressive loss of vigour occurs in all the grasses. Both Deschampsia caespitosa and the agronomic grasses Poa pratensis and Agrostis gigantea survive up to three years without fertilization, albeit in a state of reduced vigour.

We conclude that the establishment of agronomic grasses is the simplest method of revegetating these tailings, provided a high maintenance approach is used. Although Deschampsia caespitosa performs poorly under a no-maintenance regime, its ability to survive in a state of low vigour and on potentially toxic tailings could make it a valuable seed mixture component where maintenance is likely to be irregular.

ACKNOWLEDGEMENT

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LIMESTONE APPLICATION AS A TRIGGER FACTOR IN THE REVEGETATION OF ACID, METAL-CONTAMINATED SOILS OF THE SUDBURY AREA.

by

Keith Winterhalder

Department of Biology, Laurentian University, Sudbury P3E 2C6

ABSTRACT

Limestone application to toxic, barren soils triggers immediate colonization by native plant species, through germination both of the existing seed bank and of incoming wind-disseminated seeds. The primary factor triggering germination and successful establishment is the partial elimination by liming of root growth inhibition. Results of interaction experiments indicate that the detoxifying effect involves both a calcium nutrition and a neutralization component, which modify the interacting toxic effects of aluminum, copper and nickel ions. This single ameliorative act triggers colonization both through primary effects such as metal detoxification, improved mineralization of organic matter and increased phosphorus availability, and through secondary effects related to improved root growth, such as improved moisture availability and protection against frost heaving.

This year, Sudbury celebrates a century of existence as a copper and nickel mining and smelting centre. For one hundred years the landscape has been subjected to the ravages of logging, fire, soil erosion, enhanced frost action, sulphur dioxide fumigation and copper, nickel and iron particulate fallout (Winterhalder, 1978). This complex of interacting factors has given rise to 40 square miles of barren land and 140 square miles of stunted, semi-barren woodland, with areas of bare soil between the relict, coppiced trees (Watson & Richardson, 1972; Amiro & Courtin, 1981).

Following smelter closures and cutbacks and the construction of a 1,250' smokestack in 1972, it was expected that vegetation would gradually return to the barrens. With the exception, however, of the colonization of some moist valley bottoms by a tolerant ecotype of *Deschampsia caespitosa* as reported by Cox & Hutchinson (1981) and the more limited colonization of seepage areas on barren slopes by the dwarf birch *Betula pumila* var. *glandulifera*, most barren areas have remained so to this day.

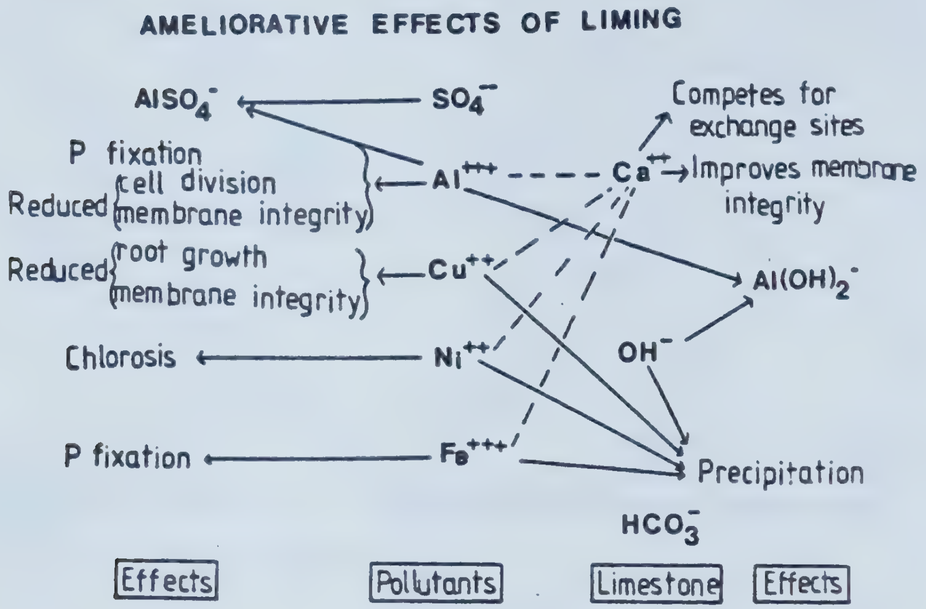
Early revegetation research showed that limestone application was essential for plant survival (Winterhalder, 1974). Later experiments showed that barren peat areas required only limestone application to initiate immediate colonization by several marsh species from the existing seed bank and from propagules that were blown in (Winterhalder, 1976). Similar experiments on mineral sites showed rapid colonization of limed sites by woody species such as *Betula papyrifera*, *Populus tremuloides* and *Salix* spp.. Even in the operational-scale Sudbury Regional Land Reclamation Programme (Lautenbach & Winterhalder, 1979; Winterhalder, 1983), which this summer employs 1,200 mining and mining-related workers, areas having a good potential seed source are treated with limestone alone, rather than with the usual limestone, fertilizer and seed.

It is clear that seed source of some of the more rapidly wind-disseminated woody species is not limiting in much of the Sudbury area, although more slowly-dispersed species such as conifers and oaks will take time to colonize, a problem that is being circumvented by the planting of sufficient of these to form a seed source. This presence of a limited woody plant seed source in the Sudbury area contrasts sharply with the suggestion that the similarly-damaged landscape at Trail, B.C. has lack of seed source as a primary limiting factor (Archibold, 1978).

I refer to limestone application as a trigger factor because it initiates a process that is not reversible and appears to be self perpetuating. Not only does succession not occur at all on many sites unless limestone is applied, but the application of limestone causes many positive feedback mechanisms to operate. For example, the organic matter formed by plants helps to tie up metals by chelation, as well as improving soil chemical, physical and moisture-retaining properties. Microorganisms stimulated by the presence of an organic substrate plus the beneficial effects of the limestone carry out mineralization, nitrification and possible nitrogen-fixing activities at an improved level. Billings (1964) defines a trigger factor as "A changed factor (or a new factor) that sets off a change of events in an environment or in an ecosystem ". The case under discussion fits the definition well.

The question arises as to how the limestone acts in such a way. It has been shown previously that Sudbury area soils are acid and metal-contaminated (Hutchinson & Whitby, 1974). Seeds either do not germinate on these soils, or they produce seedlings with stunted roots that barely penetrate the surface of the soil. Figure 1 shows the proposed toxic principles of these soils, and the hypothesized ameliorative effects of limestone application.

FIGURE 1


AMELIORATIVE EFFECTS OF LIMING
$AlSO_4^-$
SO_4^{--}
Competes for exchange sites
P fixation
Reduced cell division
membrane integrity
Al^{+++}
Ca^{++}
Improves membrane integrity
Reduced root growth
membrane integrity
Cu^{++}
$Al(OH)_2^-$
Chlorosis
Ni^{++}
OH^-
P fixation
Fe^{+++}
Precipitation
HCO_3^-
Effects
Pollutants
Limestone
Effects

Toxic pollutant effects are shown on the left, and those of limestone on the right.

It is clear that the toxic and ameliorative principles are complex in nature, consisting of several interacting factors. Experiments on germination and early growth of Agrostis gigantea (Redtop), an important revegation species in the Sudbury area, using filter paper soaked in solutions of salts of the three toxic metals, show that root growth (Figure 2) and leaf growth (Figure 3) are affected differentially by each of the three metals. Furthermore, interaction between metals can be of two sorts - synergistic or antagonistic. An example of synergism is seen in Figure 4, where the combined inhibitory effects of copper and nickel on leaf growth are greater than the sum of the parts. Aluminum and nickel, however, act in an antagonistic manner (Figures 5a & 5b), with aluminum having a "protective" effect on both root and leaf growth inhibition under increasing concentrations of nickel.

FIGURE 2

Redtop root growth at different metal concentrations.

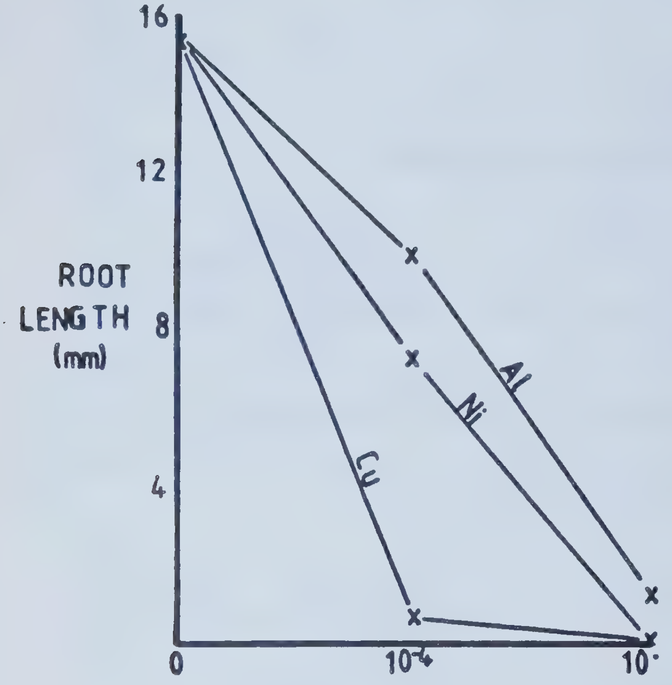


FIGURE 3

Redtop leaf growth at different metal concentrations.

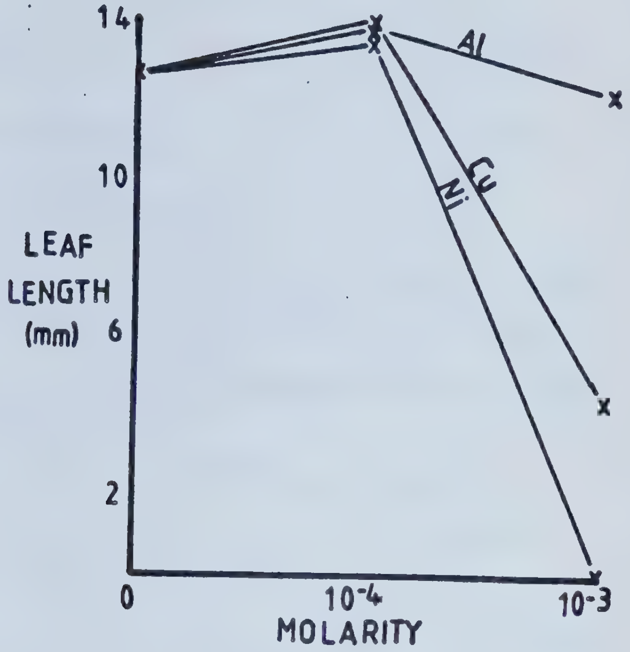


FIGURE 4

Redtop leaf growth under interacting copper and nickel treatments.

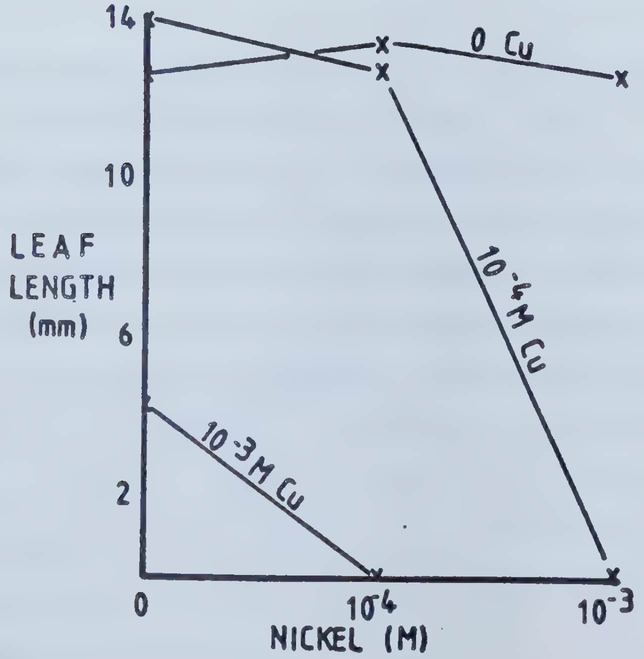


FIGURE 5a

Effect of aluminum on Redtop root growth inhibition by nickel

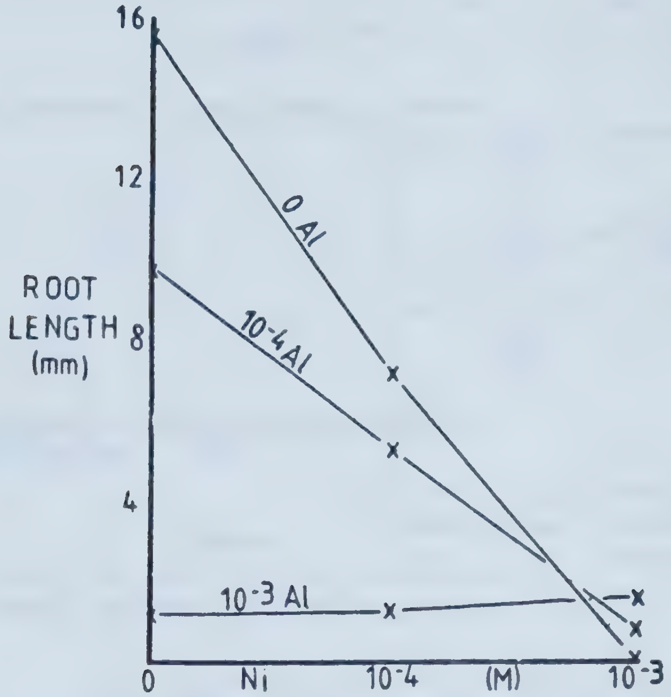
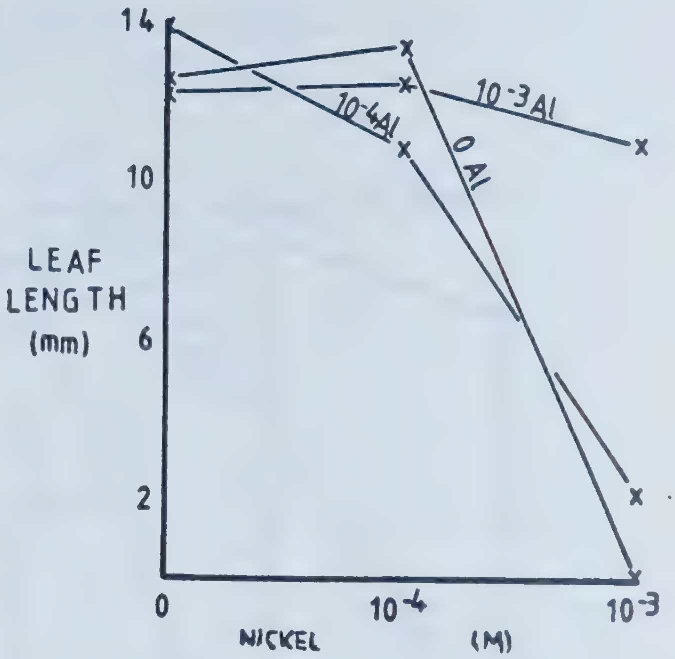


FIGURE 5b

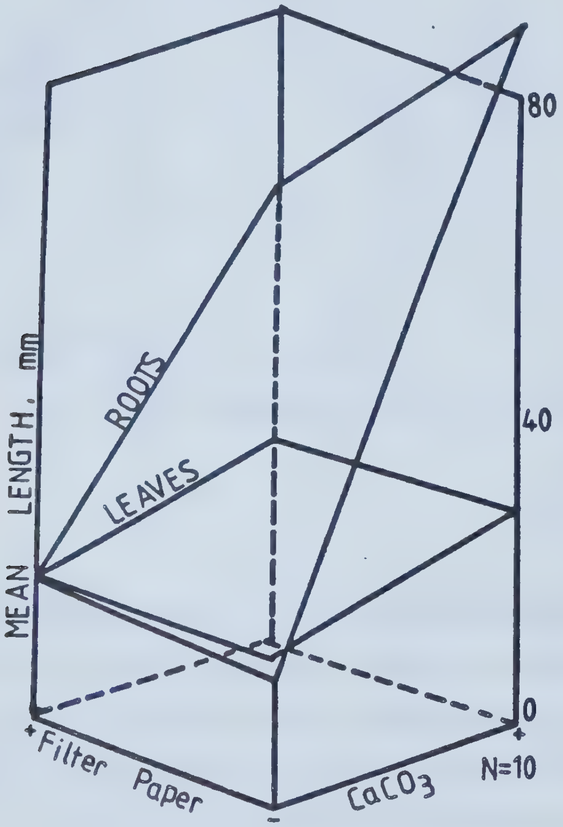
Effect of aluminum on Redtop leaf growth inhibition by nickel.



Turning to the ameliorative effects of limestone, it was first demonstrated that it involved a water-soluble principle, as did the toxic effect of the soil, by the fact that both effects would pass through a filter paper from damp soil to germinating seed (Figure 6). Note that although the ameliorative effect of limestone is more strongly expressed on bare soil in the case of root growth, the overall pattern of response is the same in the presence or absence of a filter-paper barrier.

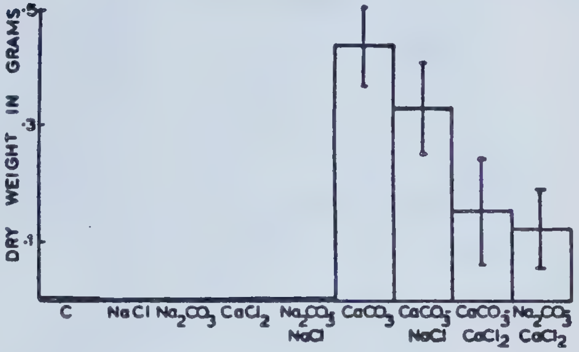
The next task was to determine whether neutralization, calcium ions or both (as hypothesized in Figure 1) had the ameliorative effect. Agrostis gigantea seeds were grown in a toxic soil treated with various combinations of calcium & carbonate radicals (Figure 7), and germination and early growth were recorded. The only plants showing satisfactory germination and survival were those under both calcium and carbonate treatment, even when these radicals were provided by two salts (sodium carbonate and calcium chloride) that were toxic when applied alone. A later in vitro experiment (Figure 8) indicated, however, that calcium alone has at least one effect on the copper-nickel-aluminum system's toxicity. The inhibitory effect of nickel on leaf growth is slightly moderated by calcium ions supplied as sulphate. Such leaf-only effects are of no benefit in the field, however, since a well developed leaf system is of little benefit to a seedling with a poorly developed root system.

FIGURE 6



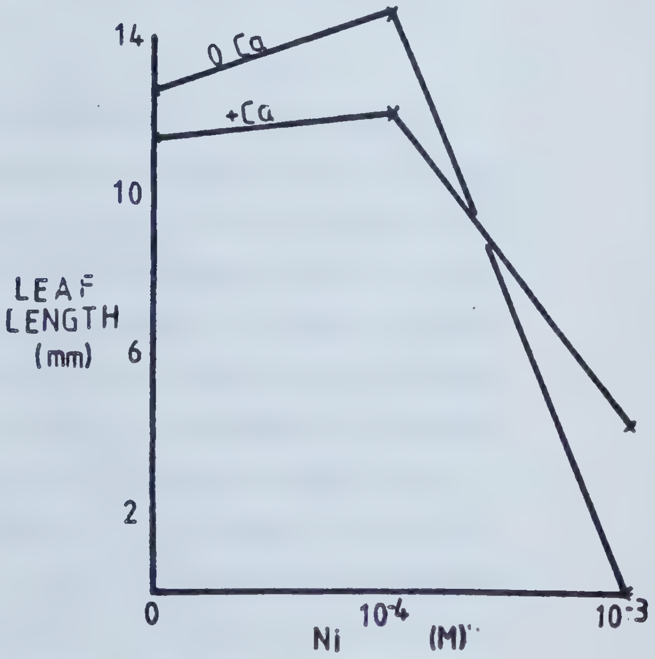
Growth of A.gigantea on toxic soil

FIGURE 7



GROWTH OF Agrostis gigantea in scrub forest soil

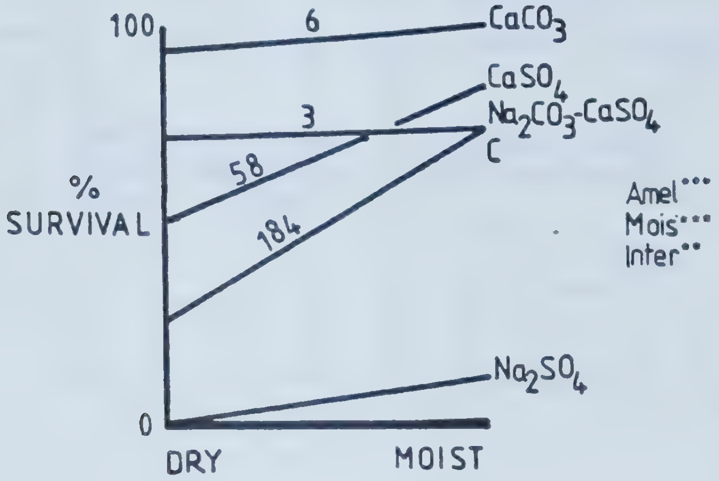
FIGURE 8
Effect of calcium ions on Redtop leaf inhibition by nickel ions.



A further experiment in which a moisture variable was introduced showed that plants receiving both calcium and carbonate were tolerant of moisture stress relative to those that did not (Figure 9). This fits well with the hypothesis that seedlings suffering from toxicity in the Sudbury area are subject to both physical and physiological drought because of the poorly developed root system and impaired membrane function, respectively.

FIGURE 9

Survival of Redtop on toxic soil treated with various ameliorants, under two moisture regimes.



The figures above the lines represent the difference between percent survival under dry and moist regimes expressed as a percentage of survival under the dry regime.

The legend indicates the significance of ameliorant, moisture regime and the interaction between the two in an analysis of variance.

Quantitative studies using 1 m^2 limed plots at various barren and semi-barren sites have indicated that spontaneous plant establishment following limestone application is not an ephemeral phenomenon, but that both summer and winter survival are good, summer survival being drought-dependant while winter survival is frost action-dependant. As shown in Table 1, even though a number of seedlings are frost-heaved (a common phenomenon in the Sudbury area where soil is not insulated by leaf litter), percent survival is good on limed plots.

Plot studies have also shown great differences in the amount of colonization depending upon the terrain. At a semi-barren birch-maple site near Garson (Figure 10), Betula numbers declined slightly in four years, while numbers of the grass Agrostis scabra rose. In terms of species importance, however, this is misleading, since percent cover by Betula rose steadily over the four years. Furthermore, when the "Initiation Factor" (mean number of plants per m^2 in limed plots as a percentage of mean number of plants per m^2 in control plots) is considered (Figure 11), there is a net rise. Fluctuations that occur in Initiation Factor are the result of spasmodic establishment and death of seedlings in the control plots, where survival is much more subject to the vagaries of the weather.

TABLE 1

Colonization and survival, Coniston limed square metre, 4 June, 1981

SPECIES	TOTAL NUMBER OF LIVING SEEDLINGS	NUMBER OF LIVING SEEDLINGS SHOWING SIGNS OF HEAVING	NUMBER OF DEAD SEEDLINGS
Salix spp.	81	36	44
Populus tremuloides	6	-	
Betula papyrifera	2	-	
Agrostis scabra	64	2	
Total living seedlings	153		

Mortality of woody seedlings 33%

Survival of woody seedlings 66%

Percentage of surviving seedlings showing frost-heaving symptoms 41%

FIGURE 10

Mean number of plants found in limed 1 m^2 plots over four years

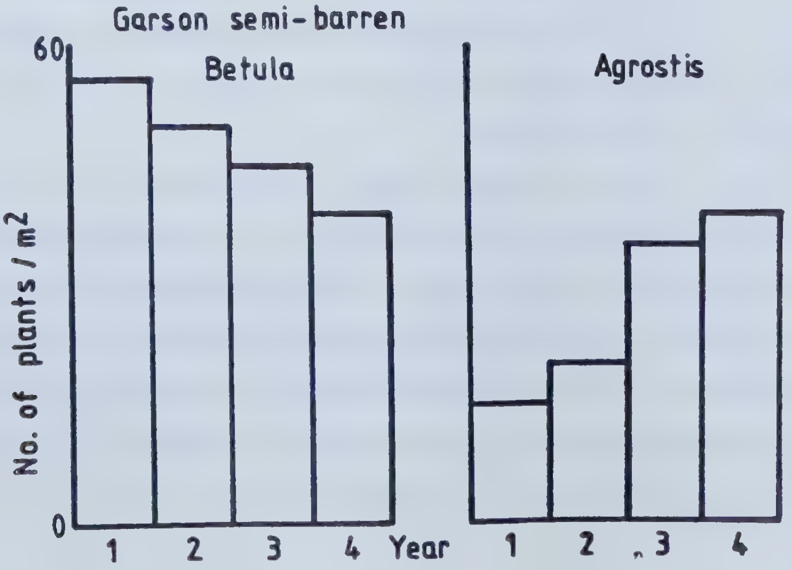
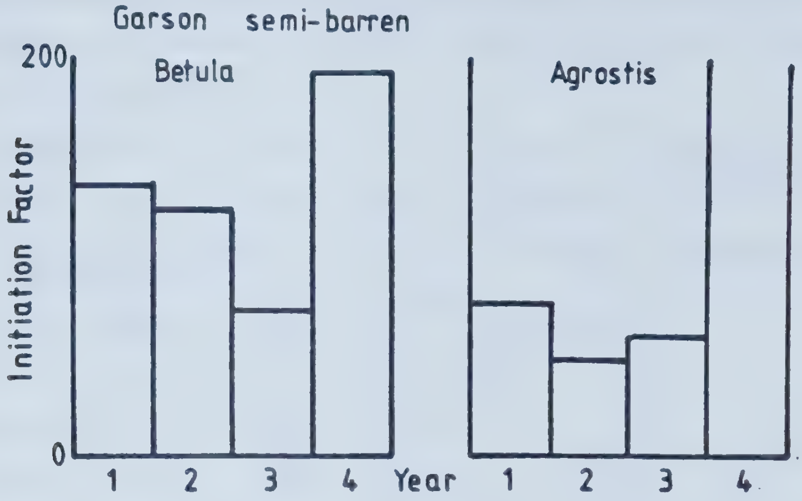


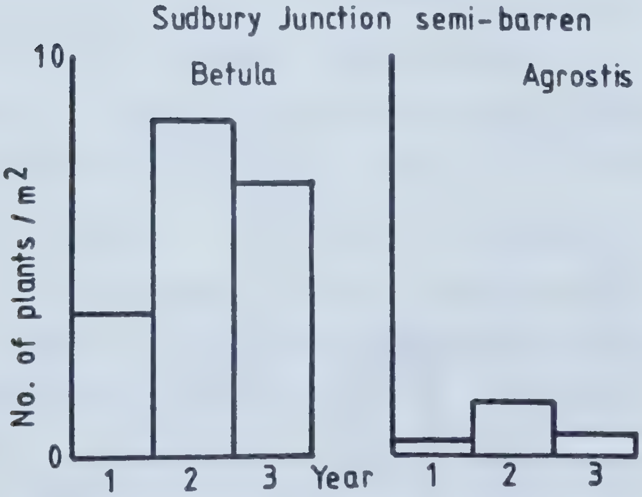
FIGURE 11

Initiation Factors (no. of plants in limed plots as % of no. of plants in control plots) for same plots as in Figure 10.



A relatively dry birch-maple site near Sudbury Junction showed a much lower level of colonization (Figure 12), while an even drier semi-barren oak site near Skead showed no colonization at all.

FIGURE 12



Limed plots on a barren slope near Coniston showed interesting divergence between top, middle and bottom of slope. The top site was dry and windswept , the main colonist being A.scabra, whose tumbleweed habit gives it the ability to colonize sites which would tend not to trap Betula, Salix and Populus propagules (Figure 13). Similarly, the bottom of the slope, with its silty-fine sand soil that packs to give a smooth surface, was colonized by A.scabra alone (Figure 14). At mid-slope, however, the soil was loamy and retained an open texture as a result of frost activity, and colonization by woody plants was heavy (Figure 15).

FIGURE 13

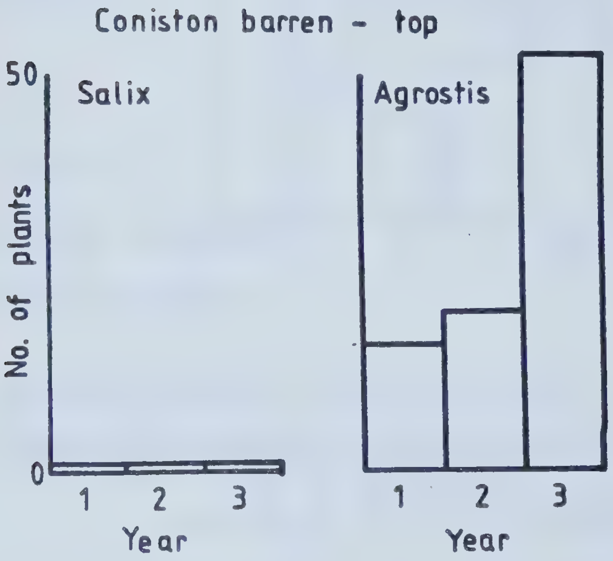

Coniston barren - top

FIGURE 14

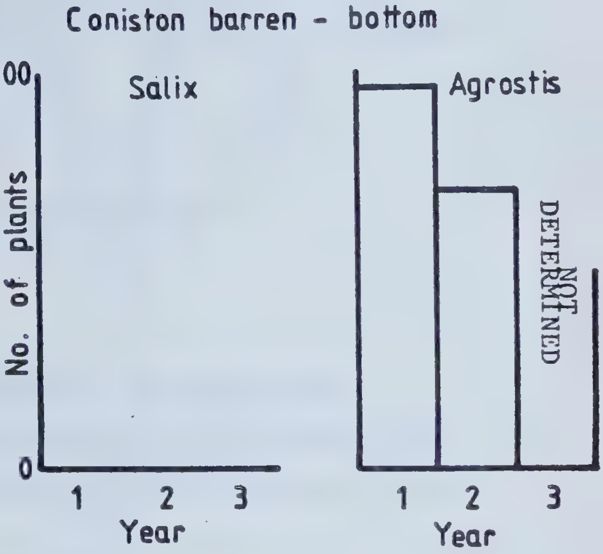
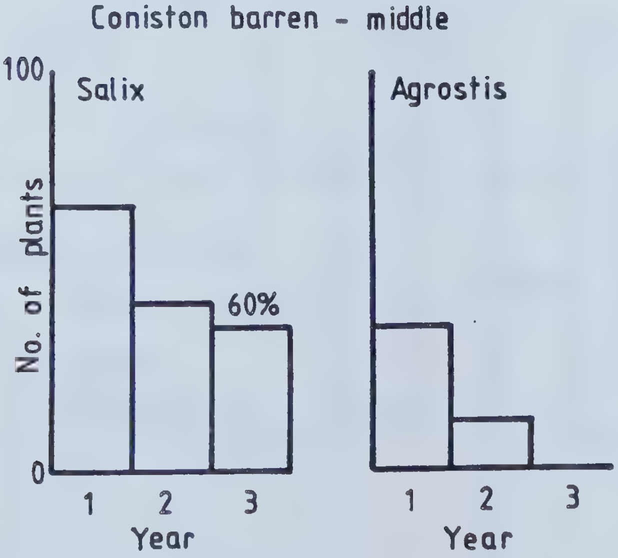

Coniston barren - bottom

FIGURE 15


Coniston barren - middle

Note that in Figure 15, although the number of Salix seedlings declined, cover reached a value of 60% after 3 years, at which time the Agrostis had dropped out altogether due to competition from the woody plants.

Preliminary work on seed sources indicates that, although there is a small dormant seed bank present in these barren soils, most of the seedlings that appear following liming result from germination of incoming wind-blown seed.

In conclusion, two points should be made on the use of limestone as a trigger factor. Firstly, from a practical point of view, the use of limestone alone, rather than lime, fertilizer and seed, is highly desirable in sites with suitable moisture and soil physical makeup for the technique to succeed. Not only is the use of limestone alone economically advantageous, but the risk of eutrophication of watercourses by widespread fertilization is avoided. A second advantage, especially from the point of view of the ecologist or phytogeographer, is the use of an existing local flora as a seed source, thus avoiding the introduction of alien species into a system that it is hoped will eventually become stable, self-sustaining and quasi-natural.

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EIGHTH ANNUAL MEETING
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EFFECT OF REVEGETATION TREATMENTS ON SOIL EROSION, PLANT ESTABLISHMENT, AND SPECIES COMPOSITION IN THE GREAT SAND HILLS OF SASKATCHEWAN

by

David G. Walker

Walker & Associates Ltd., Edmonton, Alberta

ABSTRACT

Results after 3 years are reported from a study of methods to stabilize and revegetate areas of high sand content soils in the Great Sand Hills region of southwestern Saskatchewan. Revegetation treatments examined included: (1) drill seeding, (2) wheat stubble mulch (cover crop/perennial, two-step method) (3) roll-out paper mulch (Hold/Gro), (4) straw mulch anchored with a plastic net, (5) straw mulch anchored by crimping, and (6) ground surface manipulation with the Modified Hodder Gouger. The Hodder Gouger method resulted in rapid establishment of plants and the most diversified species composition. The crimped straw mulch treatment was most effective in controlling wind erosion but contaminated the site with weed species which were still persistant after 3 years. The wheat stubbble mulch treatment was only moderately effective because seedling establishment was not completely successful on the two occasions required for the complete treatment. The netted straw and paper roll-out mulch treatments were less effect than the others and were expensive in terms of material and labor costs. The drill seeded treatment was a failure. Revegetation treatments significantly affected the species composition of invading native species and seeded revegetation species.

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INTRODUCTION

The Eastern Leg of the Alaska Highway Gas Pipeline Project begins in Central Alberta and leaves Canada near Monchy, Saskatchewan.

Environmental Concerns

Certain sections of the Eastern Leg route are recognized as being environmentally sensitive. In particular, the Great Sand Hills region of Saskatchewan is regarded as being ecologically unique and potentially difficult to revegetate after a surface disturbance (Epp and Townley-Smith 1979).

The route through southern Saskatchewan crosses the dryest region of the Canadian Prairies (Longley 1972). Long-term average rainfall is between 130 and 150 mm during the growing period, June to August. The number of days with a maximum temperature above 26°C is 55, compared to Edmonton with less than 18. Storm systems with high winds are frequent (Longley 1972) and conducive to high evaporation rates and wind erosion. Maximum wind speeds are predominantely from the south and southwest and occur most frequently during April-May and again in October when vegetative and snow cover is minimal. There is a 1 in 10 year probability of maximum wind speeds in excess of 100 km/hr.

In addition to the climatic constraints prevalent along the Eastern Leg route, soils also present revegetation difficulties. High sand-content soils are located in Alberta west of Empress in the Middle Sand Hills and north of Brooks near the Wintering Hills, and in Saskatchewan north of Maple Creek in the Great Sand Hills. Wind erosion of sandy soils results in blowouts and large moving dune complexes. Observations of previous disturbances suggest that permanent stabilization of these soils is often difficult and expensive. Repeated grading, seeding, and stabilization efforts are often required to stop the movement of sand.

Sand Stabilization and Revegetation Studies

Sponsors of the Alaska Highway Gas Pipeline Project contracted Walker & Associates Limited to investigate methods of stabilizing and revegetating sandy soils. The effect of topsoil replacement has been reported elsewhere (Walker, Paton, and Ashworth 1983). Results reported in this paper pertain to the results obtained from a study on six revegetation treatments. The investigation also examined soil compaction, native shrubs, forage productivity, fertilization, nitrogen utilization, hydroseeding, chemical stabilizers, variety selection, and ecology of native species. Soil nutrients studies conducted by Norwest Soil Research Limited and microclimatic studies conducted by Campbell Scientific Canada Corporation were other aspects of the investigation.

METHODS & MATERIALS

Test plots were established in May, 1980 on a 1 ha site located in the Great Sands Hills region of Saskatchewan, 20 km north of Maple Creek. Only the methods pertinent to the results reported in this paper are described.

Experimental Design

Revegetation Materials: All treatments except the Check were sown with a seed mixture composed of sixteen varieties of grasses and legumes potentially suitable for revegetation in the sandhills region (Table 1).

Table 1. Revegetation varieties.

Common Name	Scientific Name	Variety
alfalfa	*Medicago sativa*	Rambler
Cicer milkvetch	*Astragalus cicer*	Oxley
sainfoin	*Onobrychis viciaefolia*	Melrose
crested wheatgrass	*Agropyron cristatum*	Parkway
Russian wild ryegrass	*Elymus junceus*	Sawki
slender wheatgrass	*Agropyron trachycaulum*	Revenue
Altai wild ryegrass	*Elymus angustus*	Prairieland
pubescent wheatgrass	*Agropyron trichophorum*	Greenleaf
Canada bluegrass	*Poa compressa*	Reubens
big bluegrass	*Poa ampla*	Sherman
hard fescue	*Festuca ovina duriuscula*	Durar
streambank wheatgrass	*Agropyron riparium*	Sodar
Indian ricegrass	*Oryzopsis hymenoides*	P-2575
green needlegrass	*Stipa viridula*	Lodorm
northern wheatgrass	*Agropyron dasystachyum*	Critana
western wheatgrass	*Agropyron smithii*	Rosana

Ground Preparation: A large earthmover was used to remove vegetation and the top 15 cm of topsoil from an area of native sandhills prairie measuring 15 m by 130 m. The exposed subsoil was repeatedly cultivated with a breaking disc to level the ground and destroy all remaining root systems. This created soil conditions that might result from pipeline construction if topsoil were not salvaged: absent were most of the soil organic matter, the roots and seeds of native plants, and the soil microbiota common to the upper soil profile.

Revegetation Treatments: Six treatments and a check (no treatment) were applied in three replications. Plots measured 5 X 15 m and were oriented lengthwise with the most common direction of springtime winds (west).

The Drill Seeded Treatment consisted of sowing a revegetation seed mixture with a 2.5 m wide landscape model Brillion seed drill. The Brillion drill was chosen because, on the sandy soil at the study site, the depth of seed placement was more accurate than might have been possible with a coulter style of drill. The machine was calibrated by weighing the amount of seed dispensed after traveling a known distance.

The Wheat Stubble Mulch Treatment was applied in two steps: (1) spring sowing of a wheat cover crop and (2) subsequent fall sowing of the revegetation seed mixture. Neepawa hard red spring wheat, one of the main wheat varieties grown in Saskatchewan, was used as the cover crop and was sown with the Brillion drill. The revegetation seed mixture was broadcast sown at 20 kg/ha late the following fall; seed was incorporated by raking between the rows of standing wheat stubble.

Several brands of 'roll-out' paper mulch products are currently used in reclamation. The Hold/Gro Treatment utilized a product manufactured by Gulf States Paper Corporation which is composed of rice paper strips woven into a plastic net both of which are degradeable. After sowing the plots at 10 kg/ha with the Brillion drill, the roll-out mulch was spread and anchored by 15 cm staples spaced every 1 X 2 m.

The Straw Netted Mulch Treatment consisted of seed drilling at 10 kg/ha with the Brillion drill followed by application of a straw mulch at a rate of 2000 kg/ha. Locally grown winter rye grain straw was held to the ground with a net made of extruded polypropylene (20 mil, 2.5 X 5.0 cm mesh). The net was anchored by 15 cm staples spaced every 1 X 2 m.

The Straw Crimped Mulch Treatment was prepared by broadcast seeding at 20 kg/ha and applying winter rye grain straw at 2000 kg/ha. The straw was anchored (crimped) into the ground with a disk which had the gangs set in straight alignment. The disking resulted in 15 cm spaced rows of straw stems protruding 5 to 20 cm out of the ground. Some seed was incorporated into the soil by the disturbance produced by the straw crimping operation.

The Hodder Gouger Simulation Treatment simulated the ground surface produced by the Modified Hodder Gouger machine developed by R.L. Hodder at Montana State University, Bozeman. A series of shallow basins 15 - 20 cm deep, 75 cm wide and 150 cm long were constructed. Seed was then broadcast sown onto the plots at 40 kg/ha; some seed coverage resulted from natural sloughing of loose soil of the basin walls.

Soil Erosion Monitoring

The amount of soil movement was measured by a method adapted from techniques described by Malakouti et al. (1978) and Carr (1979). At the beginning of the study, pairs of 50 cm steel rods were placed 1 m apart in the ground so that exactly 15 cm was left above the soil surface. Four pairs of rods were randomly located within the treatment plots with the exception of the Hodder Gouger Simulation treatment on which the procedure was determined to be inaccurate. (Later modification to a larger sample area produced better results but are not reported.) Sand movement was determined with an erosion metering device consisting of a row of dowels, each 20 cm long and 1 cm in diameter, attached to a 1.05 m wide board onto which a grid of reference lines had been inscribed. The board was set on the pairs of rods and the dowels were allowed to drop to the soil surface. The profile of the soil surface, reflected by the top of the dowels against the grid, was photographed three times per year (June, August, October). Determination of the volume of soil movement was made by measuring the area of the photographic print outlined by the dowels using an electronic planimeter. Calibration was accomplished by measuring the grid itself. The area, in square cm, multiplied by the dowel diameter (1 cm) yielded the volume of soil lost or gained during each time period. Bulk density measurements of the soil were used to calculate the weight. Rate of soil movement has been expressed as metric tonnes per hectare per time period. More than 500 photographs were measured over three growing seasons (1980-1982).

Vegetation Analysis Techniques

The line interception method described by Randall (1978) and Cook and Bonham (1977) was employed to analyze vegetation. The technique provided data on ground cover and species frequency. A single 15 m transect was located diagonally across each of the three replicates for the seven treatments.

RESULTS & DISCUSSION

Soil Erosion Monitoring

In southwestern Saskatchewan, the most intense storm events of the year normally occur in early spring. The monitoring period 1980-1982 was no exception and the potential for erosion was aggravated by the complete lack of snow cover during the 1981 winter. Therefore, it was not surprising that average soil movement rates were found to be highest during the winter monitoring periods and lowest during the growing season periods. Soil erosion data has been summarized into two periods, winter and summer, and results presented in Figure 1.

Treatments lacking measures to temporarily still the movement of sand produced unsatisfactory erosion control. The Check and Drill Seeded treatments continued to record seriously high rates of soil movement. A rate of 150 tonnes/hectare (t/ha) corresponds to 1 cm of soil and the loss or deposition of amounts of this magnitude can be expected to inhibit plant establishment. The Drill Seeded treatment recorded rates of soil movement which exceeded the Check treatment. This was most probably due to the fact that the Brillion seed drill produced a flat, smooth ground surface conducive to the movement of soil particles. During the first monitoring period, the Hold/Gro treatment recorded the highest rate of gain as moving soil particles were trapped under the fabric. By fall, the plastic net began to photodegrade and as the mulch fabric disintegrated, erosion losses were recorded. Rapid establishment of the cover crop in the Wheat Stubble Mulch treatment provided good erosion control during the first monitoring period and the standing stubble was sufficient to provide good erosion control through the first winter season. Both treatments utilizing a straw mulch resulted in good erosion control throughout the monitoring periods but the crimped treatment was more effective than the netted treatment because the staples did not completely anchor the straw under the net. The Hodder Gouger treatment, while not monitored quantitatively, also provided good erosion control by restricting the movement of sand to the area within and between the gouged basins.

Since five of the treatments appeared to provide levels of erosion control sufficient for plant establishment, the question of cost of application becomes pertinent. The Straw Net and Hold/Gro treatment are both expensive in terms of material and labor. The Wheat Stubble treatment requires a second input of manpower and machinery and was judged to be a riskier method because two consecutive periods of spring weather favorable to plant establishment were required. In addition, portions of the plots where establishment of the cover crop was poor later recorded a poor stand of perennial species.

The Straw Crimped and the Hodder Gouger were concluded to be the most cost-effective treatments examined in the study. Both, however, have disadvantages. The Hodder Gouger treatment is effective in controlling erosion only as long as the configuration of the basins persist. Once filled, the Hodder Gouger treatment becomes no more effective than the Drill Seeded or Check treatments. In this study, Hodder Gouger basins remained well-shaped long enough for adequate plant establishment but higher rates of soil movement are to be expected on areas larger or more exposed to winds than the experimental plots.

The Straw Crimped treatment has the disadvantage of invariably introducing weed seeds to a disturbed site and the persistence weeds could reduce the quality of reclamation. The straw used in this study was contaminated with Russian thistle (*Salsola pestifer* Nels.) and the species was still the most common component (35% frequency) of the vegetative cover of both straw treatments the after 3 years. This problem was overcome somewhat during actual reclamation of the pipeline in the sandhills by utilization of grass straw obtained from fields used to grow pedigreed seed. Seed production fields which qualify for pedigreed status are generally weed-free.

Plant Establishment

Interspecific Competition: The combination of a large number of species in the seed mixture, arid climate, and coarse, nutrient poor soil created conditions of intense competiton between plants. Of the sixteen varieties sown, only three were present in significant quantities throughout all treatments - Parkway crested wheatgrass, Rambler alfalfa, and Durar hard fescue. Other species recorded in lower numbers or distributed unevenly among the treatments were Revenue slender wheatgrass, Reubens Canada bluegrass, Sodar streambank wheatgrass, Greenleaf pubescent wheatgrass, Oxley Cicer milkvetch, and Melrose sainfoin. Evidence from another part of the study supported the fact that interspecific competition was the reason for the lack of success of other varieties rather than poor adaptation. Most of the varieties were successful when grown in single-species rows, free from competition.

Early Growth Patterns: Both the Hold/Gro and Hodder Gouger treatments were observed to be different from the others in promoting rapid early growth. Soil temperature under the Hold/Gro mulch was recorded to be up to a degree Celsius warmer than the adjacent unmulched soil. As summer progressed, the early advantage appeared to subside probably as a result of adversely high daytime termperatures. The Hodder Gouger treatment produced early rapid growth of plants and the positive effect persisted throughout the season. By fall, growth of slender wheatgrass, Canada bluegrass, and crested wheatgrass was clearly advanced over the same species in other treatments. Each gouger basin contained numerous plants in flower in contrast to the same species only at the 5-7 leaf stage in other treatments.

Plant Cover: Results of a vegetation analysis of the revegetation treatments after 2 years are illustrated in Figure 2. The Hodder Gouger treatment was outstanding in producing a total vegetation cover equivalent to that of the native prairie (55%). Plants were crowded in the basins where the cover of revegetation species was almost 100%. The area between basins was almost devoid of revegetation species but was being colonized by native species.

By the end of the third growing season, gouger basins had become shallow depressions and the advantage of the modified microtopography had diminished. Edge effects from adjacent plots and surrounding buffer zones were also in evidence as all treatments recorded total vegetation ground covers which were not significantly different (25-35%).

Species Composition

Species Richness: Species richness refers to the number of different species found within a given area. The revegetation species richness value for the Hodder Gouger treatment (Figure 3) was significantly higher ($P<0.05$) than all other treatments except the Staw Crimped. Native species richness values for all treatments were not significantly different.

Species Performance Patterns: Several species were selected to illustrate the effect that treatment had on performance of individual species. Results are presented in Figure 4. Pasture sage (*Artemisia frigida*), an invading native forb, was most frequent in the the Hold/Gro mulch treatment while another invading native species, northern wheatgrass (*Agropyron dasystachyum*), was least frequent in treatments with a straw mulch. The frequency of revegetation species was also affected by the treatment. Rambler alfalfa was a major component in the two straw mulch treatments and the Hodder Gouger treatment but not other treatments. Crested wheatgrass was present in a much higher proportion in the Hodder Gouger treatment than in other treatments. Explanation of why revegetation treatments affect the distribution of individual species can only be based on speculation without more detailed studies. Factors such as competitive ability, rate of establishment and growth, tolerance of low nutrient status and soil moisture, and method of reproduction (invasion by seed or roots) are suggested as the most probable reasons.

CONCLUSIONS

Of the six revegetation treatments examined in the study, the Hodder Gouger treatment was determined to be the most effective method of establishing a rapid and diversified vegetation cover. The level of erosion control provided by the Hodder Gouger was determined to be adequate for areas of moderate erosion potential but may not be sufficient in localized areas prone to erosion (wind erosion focal points) such as hill tops. The Straw Crimped mulch method was effective in controlling the movement of soil. The unwanted introduction of weeds is a serious drawback of the treatment. Other treatments were judged to be more expensive, carried a higher risk of failure, or less effective in terms of erosion control and plant establishment.

Revegetation treatments affected the plant ecology of the reclaimed site. The species composition of invading native species and revegetation species was significantly altered. Reclamation of pipeline rights-of-ways in pastures grazed by cattle should result in a species composition which matches the surrounding vegetation in terms of productivity and grazing preference in order to avoid the concentration of animals on the disturbance. Therefore the selection of species and the composition of the seed mixture should be considered for good results.

ACKNOWLEGEMENT

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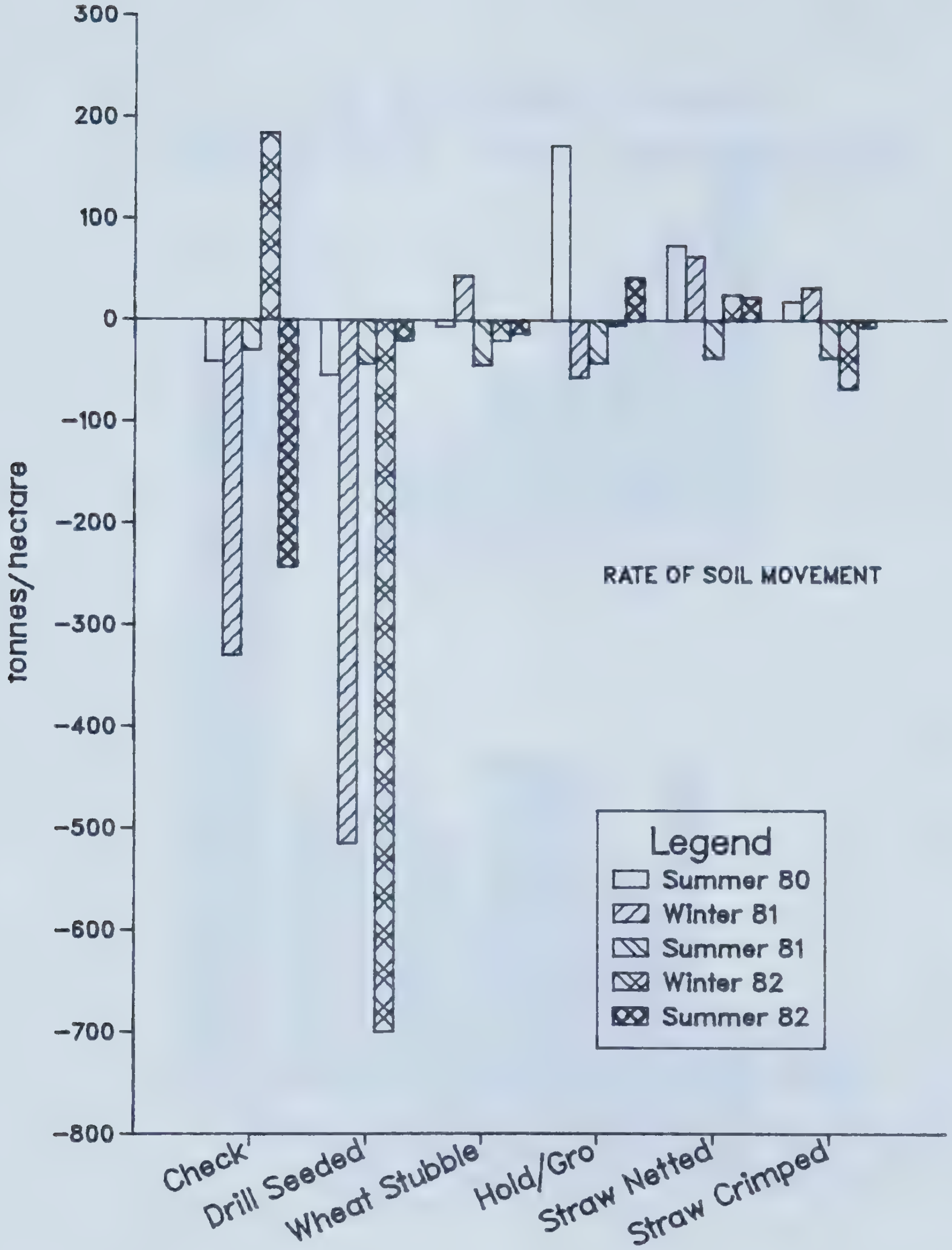

Figure 1. Effect of revegetation treatment on rate of soil movement.

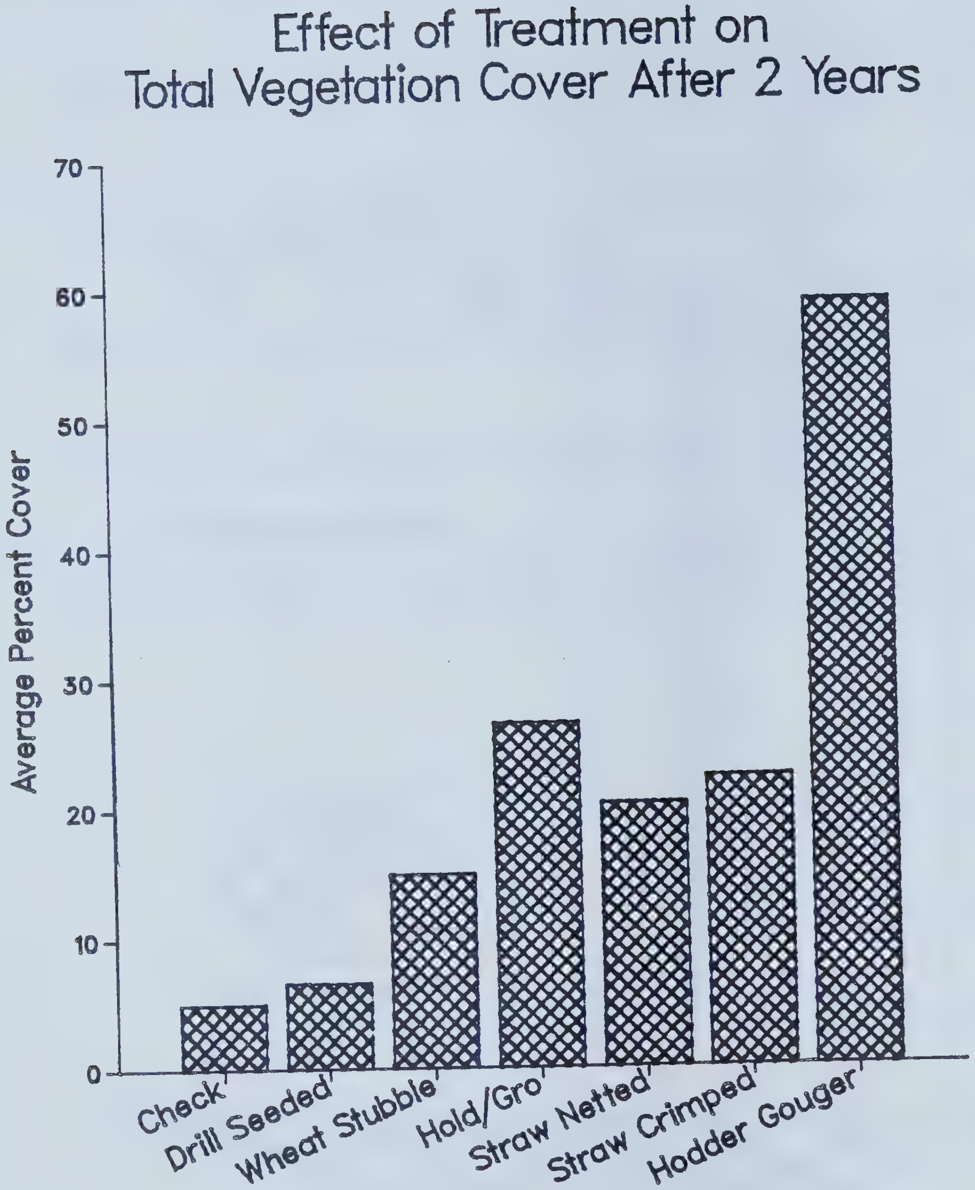

Figure 2. Effect of revegetation treatment on total vegetation cover after 2 years.

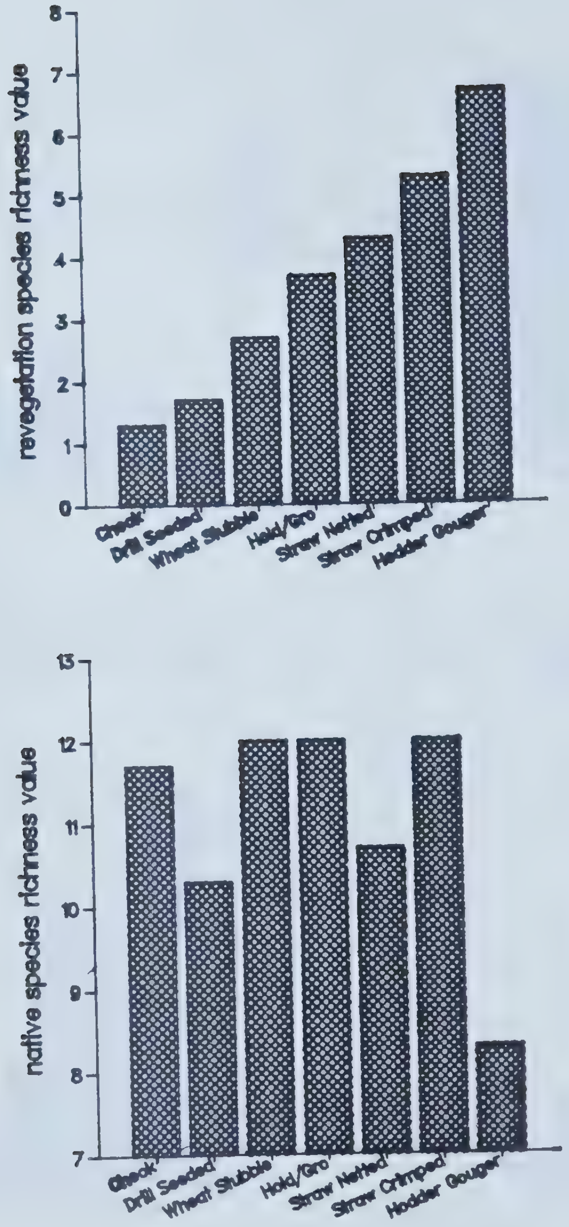

Figure 3. Effect of revegetation treatment on species richness value.

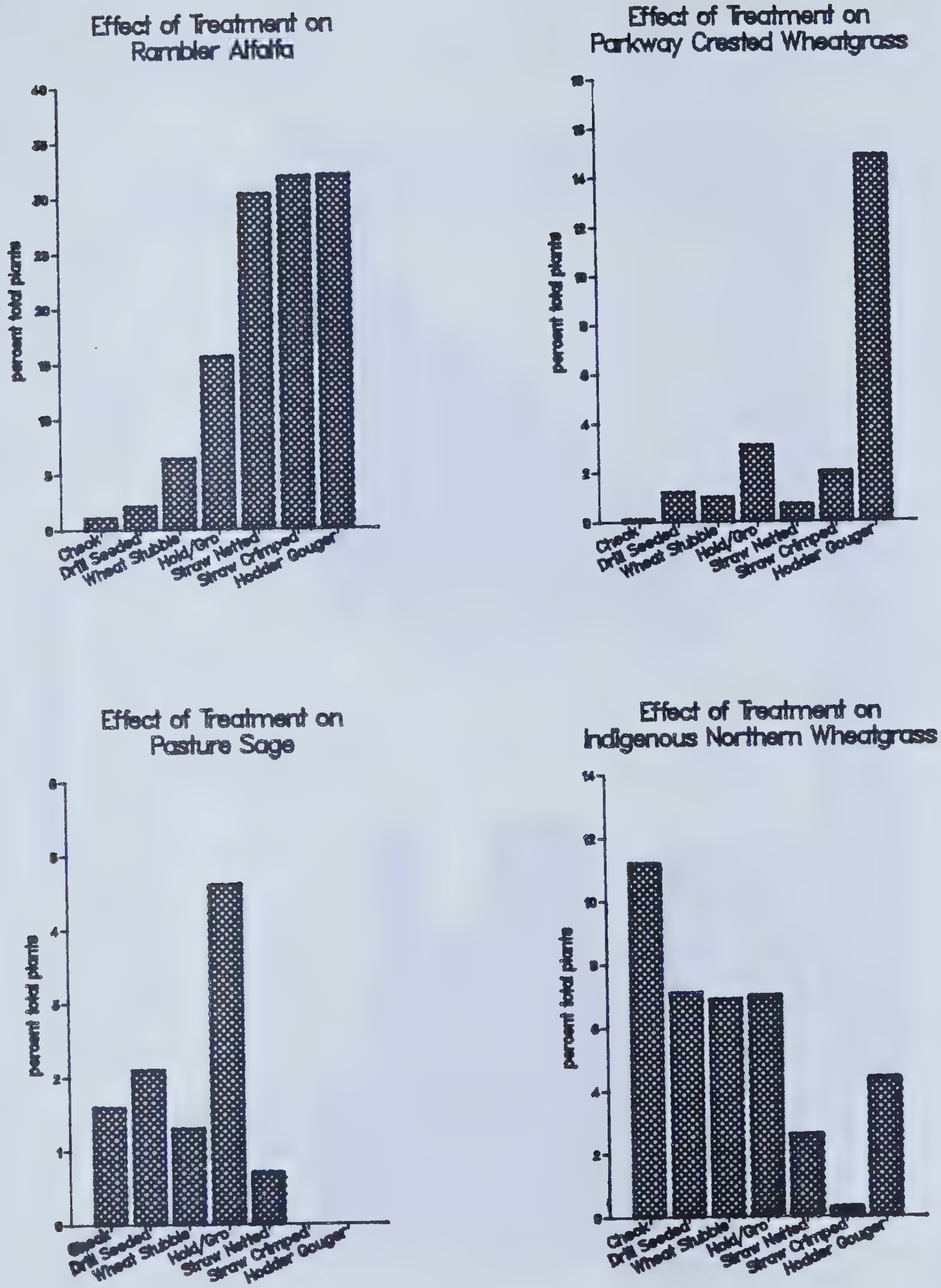

Figure 4. Effect of revegetation treatment on frequency of selected species.

THE PEDOLOGICAL PROPERTIES OF TAILINGS DERIVED FROM IRON AND URANIUM MINING AT MARMORA AND BANCROFT, ONTARIO.

G. K. Rutherford,
Angela Pawling,
Department of Geography,
Queen's University.

and

G. W. vanloon,
Department of Chemistry,
Queen's University.

ABSTRACT

Tailings from two mining operations refinning oxide ores, iron oxide at Marmora and uranium oxide near Bancroft, Ontario have been subjected to typical pedological analyses in order to compare their properties as potential growth sites. The tailings have sandy loam to loam textures, low air-dry and available moisture, are slightly acid and are considerably lower in organic carbon and sulphate than normal soils.

INTRODUCTION

Tailings are the waste products resulting from the beneficiation of metal ores and consist of country rock, composite rock and ore fragments that are considered uneconomical to process further. As these deposits become employed as growth media for plants it would be of interest and practical use to establish their pedological properties so they may be compared with soils. Experience indicates that fertilizer trials and norms established on soils do not apply adequately when applied to tailings. Once the pedological properties are better appreciated more realistic fertilizer and plant establishment programmes may be contemplated.

Rutherford and coworkers (1982) have established a number of the common pedological properties of tailings from Ni, Pb-Zn and Au mining in the Sudbury area, Ontario. The former two operations involved extraction from sulphide ores and the latter a pegmatite ore. Crowder and associates (1982) have shown some of the site factors affecting vegetation on the nickel-sulphide ores one of these sites at Copper Cliff near Sudbury.

Two major factors affecting vegetation at Copper Cliff and that on sulphide tailings in general are the presence of toxic heavy metals in the tailings and the development of acid conditions from the sulphides by bacterial action. Geochemically, these are known as the chalcophile ore elements but some other ores are dominantly associated with oxides and called the siderophile elements. Two of the latter are iron and uranium although the former is commonly associated with the chalcophile elements also. The object of this article, then, is to establish some pedological properties of tailings derived from oxide ores namely iron at Marmora and uranium at Bancroft, Ontario.

MATERIAL AND METHODS

Field

The tailings were sampled from the old Marmoraton (Bethlehem Steel) iron ore mine in Marmora and the Madawaska uranium mine near Bancroft. At Marmora pits were dug at sites to accommodate variables such as age of the tailings, geomorphic situation and vegetation differences. The same sampling procedure was applied at Bancroft but, in addition, samples were taken from an active tailings pond for comparative purposes. In addition to vegetation, geomorphic situation and relative age, note was made of the horizonation, texture and colour. Appropriate horizons were sampled and placed in plastic bags and transported to the laboratory. A brief description of the sites and samples is rendered in Table 1.

Laboratory

Upon returning to the laboratory the samples were air dried, and passed through a >2mm sieve. pH was measured in a suspension of 0.01 M $CaCl_2$, water content was determined by drying samples to 105°C and loss on ignition by drying further to 550°C. Organic carbon and total sulphur were determined by the Leco furnace. Particle size was established by hydrometer and the sand sieved for fine, medium and coarse fractions. Exchange cations were extracted with 1 M NH_4OAc at pH 7. The dithionite-, oxalate- and pyrophosphate iron and aluminum, sulphate (extraction with 0.01 M $Ca(H_2PO_4)_2.H_2O$), and bicarbonate soluble phosphorus were determined by methods outlined by the Canadian Soil Survey Committee (1978). Total elemental content was determined by dissolution with HF, HNO_3 and $HCLO_4$ and atomic absorption, soil moisture tension with a pressure plate membrane and total N by the Kjeldahl method (semimicro).

THE PHYSICAL SETTING

The geographic situation of the mining sites is rendered in Figure 1. Belleville being situated on the Bay of Quinte in Lake Ontario some 200 km east of Toronto. The average yearly precipitation in Marmora is approximately 900 mm of which 750 mm falls as rain. At Bancroft the precipitation is slightly higher. The yearly mean temperature at Marmora is 8°C ranging from 21°C in July to a mean low of -8°C in January. The Marmora area has been cleared of the coniferous-hardwood vegetation which was present at the time of European occupation and most is being used as arable or pasture land. At Bancroft, the original vegetation has been logged for over a century but much of the area is still under forest.

Bancroft is geologically on the Canadian Shield with granitic and gneissic acidic rocks with Podzolic and Brunisolic soils where the soil mantle is appropriately thick. At Marmora a thin layer of Paleozoic sediments covers the underlying Canadian Shield rocks.

The ore body at Marmora occurs as stringers and irregular masses of magnetite mixed with pre-Cambrian limestone and intrusion dikes. The ore body was about 700m by 130m and represented a replacement of the pre-Cambrian limestone overlain by 40m of flat-lying Paleozoic limestone. Mining ceased in the mid-1970's. Average grade of the ore about 35% iron.

On the higher (older) tailings site oats were planted in the spring of 1976 and fertilized (200 kg/ha 34-0-0, Acroprill and 250 kg/ha 5-20-20). In the autumn, the oats were disced into the ground, more fertilizer was applied and perennial rye, blue grass, timothy, red top, creeping red fescue, Oregon tall fescue and yellow clover. In the spring of 1977, more fertilizer was spread and crown vetch were planted.

The uranium ore body at Bancroft (Madawaska) occurs as a pegmatite intrusion into the pre-Cambrian Shield rocks. Production of the 0.112% U_3O_8 ore ceased in 1964 but the mine was reactivated in 1975. Production ceased again in 1982 when the mine was placed on stand-by. The radioactive minerals occur in bodies of leucogranite, elucogranite pegmatite and syenite cutting metagabbro and gabbroid amphibolite. There is, thus, an older tailings area which an attempt was made to vegetate and is referred to as the older area in this text and a younger area of tailings which were piped out on to a lower area and presently constitute the southern flank of the main tailings body. These are unvegetated and are referred to as the younger tailings area.

RESULTS

The results of morphological, chemical and physical analyses of these tailings are presented in Tables 1 through 4.

The general soil texture both at Marmora and Bancroft is sandy loam to loam whilst bands of extremely high clay content are interspersed through the former deposits. At Marmora these clay layers are usually dull brown but may vary between olive black and purple. At Bancroft the colours vary from dark yellowish brown to yellowish gray and gray. The texture of the Marmora materials are somewhat sandier than the surrounding Gray-Brown Luvisolic soils but quite similar to the Podzols and Brunisols on the Canadian Shield at Bancroft. Considerable and not uncommonly there are abrupt horizontal and vertical changes in texture which is a function of distance from the outlet pipe at the time.

Available moisture, between 1/3 and 15 bar, is the water held between wilting point and field capacity. A normal sandy loam subsoil horizon would appear to have about 10% available moisture whereas these tailings vary between 4 and 1%. The finer textured tailings have higher available moisture and in fact some of the clay layers attained values of 31%. These clay layers are usually in the subsoil and of little value in establishing vegetation. One of the clay tailings samples from Bancroft had an available moisture content of only 5%.

pH values of both sites vary only between pH 5.0 and 6.0 and may thus be classified as moderately to slightly acid. There appears to be no discernible depth/pH at either site. The pH of Podzol soils in the area range from 3.3 in the Ae to 4.7 at depth. The tailings are, then, markedly less acidic than the natural surface soils.

The organic carbon values are, as suspected, much lower than those of the natural soils of the surrounds which have values of about 1% in the Ae, 7% in the Bhf, 3% in the Bf and 0.3% in the C horizons. Reasonably arable soil would contain about 2% organic carbon. At the old site at Marmora, moss covered topsoils contain 0.02% and under patches of yellow clover 0.11%. On the younger site, vegetated soil contained 0.165% organic carbon and at an unvegetated site 0.015%. At Bancroft organic carbon was recorded in the fresh tailings but this is likely caused by organic materials in the refining process. The older tailings which supported some vegetation have notably higher organic carbon contents but as yet much lower than natural or cultivated soils.

At Marmora, sum of exchange cations varies from about 1 meq/100g to 5 meq/100g on the older sites and up to 30 meq/100g on lower, or younger sites. The younger site is down drainage from limestone spoil so that the high Ca values are derived therefrom. Exchange Na is almost undetectable, exchange K seldom more than 0.1 meq/100g. Fresh tailings from the uranium refining process at Bancroft have corresponding values of 65 to 100 meq/100g which is a function of dolomite added during the process. On the older sites the sum of exchange cations increases from 1 meq/100g at the surface to about 30 meq/100g at depth. It appears that these materials at both places leach rather quickly to produce a growth medium naturally low in plant nutrient cations.

Total N would, in natural soils, be closely or wholly associated with the organic matter. For tailings, the N could be a part of chemicals added during the refinning process. Natural surface soils in the areas contain about 0.8% N and arable soils about 0.4%. Although the tailings showed considerably less than these values, it is interesting to note the affect of legumes over a rather short period. Subsoils under yellow clover had been enriched to aobout 0.165% N so that much of this would be directly related to the vegetation type. The influence of vegetation on the old sites at Bancroft is clearly revealed in the nitrogen analyses.

For total and SO_4-S comparative soil data is not available for Canadian soils. The SO_4 content appears to be typical for young soil materials. At Marmora substantial increases in total S at depth is not matched by corresponding SO_4 increases. At Copper Cliff near Sudbury, Rutherford and coworkers (1981) investigated tailings from sulphide ores and found that the SO_4 contents were about one order higher than at Bancroft/Marmora and that there is a corresponding increase in total S with depth, which was not matched by appropriate increases in SO_4-S. The high values for fresh tailings likely represent chemicals used in the refinning processes. At Marmora, total S is commonly 20 times more than in normal soils but is approximately the same at Bancroft.

The information provided by the Al and Fe analyses enables an estimation of the degree of soil development to be made. For dithionite, -Fe values

>1% are indicative of weathered sediments and may be > 3.3% in some Podzols. Although some of the tailings may have values approximating these, it is suspected that some of the crystaline oxide minerals of the ore may be contributing. Ordinarily oxalate-Fe would be considered a useful indicator of soil development. The values for this in Table 3 are generally markedly lower than those expected for Podzolic soils and again it is suspected that the high iron ore materials would tend to inflate these values compared with glacial sediments from the Canadian Shield. Pyrophosphate-Fe which is a measure of the organic matter bound iron are about one order lower than for natural soils.

Dithionite-Al is generally one order lower than for soils although the oxalate values are markedly hgiher than those expected for normal soils. However the interpretation of these data for such materials is presently doubtful. Pyrophosphate-Al values which reflect organic matter content are an order lower than for normal soils.

The purpose of total cation analyses is to identify, if possible, gross changes in chemical composition with depth. The analyses rendered in Table 4 are remarkably similar suggesting that profile parent materials have remained rather constant during pond filling and no marked changes as a result of leaching and pedogenetic processes may be observed. The marked difference in total chemical composition between the two areas is apparant but the results for both materials corroborate earlier finds by Hawley (1979).

SUMMARY

Tailings from two mining operations refinning oxides have been subjected to analyses applied to soils in order to compare their properties as potential growth sites.

The tailings have sandy loam to loam textures, low air-dry and available moisture, are slightly to moderately acid and are considerably lower in organic carbon and sulphate than normal soils. There is little evidence of pedological development but the parent materials although different at both sites have had rather constant composition during pond formation. Both materials have low exchangeable cations and are not naturally fertile growth sites.

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Table 1. Site and sample descriptions of some tailings profiles from Bancroft and Marmora, Ontario.

Sample Number	Depth cm	Marmora
1		Oldest tailings site; sparsely vegetated with individual tufts mainly in drill rills; continuous 2 cm moss cover
1 - 1	0 - 1	10Y 3/3 olive black sandy loam; common fine roos; dries quickly to become powdery
1 - 2	1 -20	2.5GY 3/1 dark olive gray sandy loam; slightly firm; common fine roots to 10 cm depth
1 - 3	20-60	10YR 4/2 olive gray silty loam to sily clay loam; friable; sedimentation pattern
1 - 4	60-90	10Y 3/2 olive black loamy coarse sand; sedimentation banding coarse and fine textured bands
1a		Same area as 1 but located in dense yellow clover patch
1a- 1	0 - 1	10Y 5/1 gray sandy loam; thin complete moss cover
1a- 2	1 - 9	5GY 6/1 olive gray silty clay to silty clay loam; banded
1a- 3	9 -15	2.5GY 3/1 dark olive gray sandy loam; common fine roots
1a- 4	15-42	7.5YR 5/4 reddish brown sandy loam with some 1-2 cm 10Y 3/2 olive black clay horizons
1a- 5	42-100	10Y 3/2 olive black coarse sandy loam stratified with thin layers of lighter colour and finer texture
2		Similar situation to 1
2 - 1	0 - 6	10Y 4/2 silty clay with 7.5YR 5/4 olive brown bands
2 - 2	6 -45	10Y 5/2 olive gray silty loam; mottles
2 -3b	51-53	10Y 4/2 olive gray silty loam with frequent medium 7.5YR 5/6 bright brown mottles
2 - 3	53+	5G 5/1 greenish gray clay
3		Unvegetated youngest tailing pond
3 - 1	0 - 2	10Y 4/2 olive gray loamy sand
3 - 2	55-60	10Y 3/2 olive black loamy sand with thin 1 cm clay bands
3a		Youngest tailing pond with patch of yellow clover
3a- 1	0 - 2	
3a- 2	50-55	

Madawaska-Bancroft

4		Active tailing pond; reddish brown clay lenses in loamy sand
4F- 1	0 - 5	At outlet pipe; fresh tailings
4F- 2	5 -15	
4 - 1	0 - 5	In pond 25m from outlet
4 - 2	40-50	Old vegetated tailings pond with mosses, wild strawberry and grass tufts
5 - 0	0 - 3	10YR 3/4 dark brown sandy loam
5 - 1	3 -10	10YR 4/6 brown iron oxide gravel; few fine roots
5 - 2	10-23	2.5Y 5/1 yellowish gray loamy sand
5 - 3	23-48	10Y 3/2 olive black clay bands with 10YR 5/8 yellowish brown sandy loam
5 - 4	48-88	2.5Y 5/1 yellowish gray loamy sand
6		Old naturally vegetated tailing pond with popular and birch covered with gravels and crushed rock
6 - 1	1 -10	5YR 2/3 very dark reddish brown gravelly sandy loam
6 - 2	10-27	2.5Y 5/2 grayish yellow sandy loam with fine clay bands
6 - 3	27-35	5Y 5/1 gray medium sand; strongly stratified
6 - 4	35-90	5Y 5/1 gray loamy medium sand with fine clay bands

TABLE 2. Some physical data for tailings from Bancroft and Marmora, Ontario.

Sample Number	Depth cm	Air Dry Water %	L.O.I. %	Particle Size % cl	si	sa	fs	ms	cs	Moisture Retention % 0.1	0.3	2	10	15
1 - 1	0 - 1	1.95	0.157							4.4	1.2	1.2	0.93	1.22
1 - 2	1 - 2	3.72	0.071	14.09	17.77	68.14								
1 - 3	20-65	7.25	0.071	15.52	30.17	54.31	38.43	11.12	4.76					
1 - 4	65-90+									2.8	1.1	1.2	0.85	0.71
1a- 1	0 - 1	8.71	2.291											
1a- 2	1 - 9	3.61	0.244	14.56	36.03	49.41	34.55	9.67	5.18	10.7	3.9	3.0	1.79	1.45
1a- 3	9 -15	2.88	0.060											
1a- 4	15-42	14.53	0.057	17.27	46.97	35.76	33.48	1.00	1.28					
1a- 5	42-100+	4.21c		9.62	9.53	80.85	44.62	24.23	12.00					
2 - 1	0 - 6	30.15	0.995	23.38	71.62	5	4.00	1.00	0	29.8	14.1	12.9	5.44	5.94
2 - 2		16.71	0.088											
2 - 3	55+													
2a- 2	28-55	7.42	0.077	15.78	22.32	61.90	60.05	1.11	0.74					
2a- 3	21-28	33.21								32.5	25.0	22.9	12.35	5.36
2a- 4	55+													
3	0 - 2	3.11c		8.70	14.33	76.97	71.35	5.31	0.31	3.5	1.4	1.1	0.66	0.54
3	50-60													
3a	0 - 2													
3a	50-55													
4a	0 - 5													
4a	5 -15													
4	0 - 5									4.4	2.6	1.5	1.12	1.43
4	40-50	9.67c		10.15	11.18	78.67	71.98	6.49	0.20					
5 - 0	0 - 3	4.36	1.032							2.5	1.4	1.2	1.2	1.04
5 - 1	3 -11	6.49	0.228							4.8	3.0	2.2	2.3	1.78
5 - 2	11-23	2.30	0.159											
5 - 3	23-49	25.73	0.387	16.13	39.99	43.88	73.20	0.46	0					
5 - 4	49-55													
6 - 1	1 -10	4.23	0.214							5.5	2.9	2.3	1.5	1.07
6 - 2	10-27	12.11	0.246	15.66	19.43	64.91	62.19	2.40	0.32					
6 - 3	27-35	2.63	0.209											
6 - 4	35-50	8.18c		10.52	10.42	79.06	43.36	35.38	0.32					

L.O.I.= Loss on Ignition to 550°C; cl=clay (2µm); si=silt (2-65µm); sa=sand (65-2000µm); fs=fine sand, ms=medium sand cs=coarse sand

TABLE 34 - CHEMICAL PROPERTIES OF TAILINGS IN THE [illegible] AREA

		[illegible]				[illegible]						[illegible] (%)			[illegible]		
Site	pH*	Na	Mg	Ca	K	Total	Organic	Inorganic	Mn	% S	Sulfate*	Dith.	(10-3)	Total	(10-3)	Dith.	Oxalate
1-1	5.23	ND	0.23	1.40	0.08	0.450	0.020	0.430	0.011	1.18	0.0457	0.103	2.42	0.514	14.81	0.613	0.502
1-2	5.08	ND	0.24	2.54	0.14	0.475	0.010	0.465	-	2.80	0.0314	0.08	1.03	0.422	8.303	0.288	0.328
1-3	5.63	ND	0.13	2.07	0.07	0.485	0.015	0.470	-	2.18	0.0415	0.06	ND	0.456	7.215	0.261	0.222
1-4	5.47	ND	0.25	2.47	0.07	0.360	0.025	0.335	-	3.61	0.0134	0.157	ND	0.474	10.11	0.454	[illegible]
1a-1*	5.71	ND	0.23	2.32	0.14	0.600	0.110	0.490	0.065	1.33	0.0188	0.13	ND	0.506	12.03	0.523	0.338
1a-2	5.00	ND	0.20	1.51	0.11	0.505	0.025	0.480	0.049	1.61	0.0138	0.137	3.42	0.338	8.48	0.501	0.104
1a-3	5.11	ND	0.13	1.30	0.10	0.550	0.005	0.545	0.53	1.72	0.0252	0.050	1.03	0.474	0.25	0.104	0.104
1a-4	5.13	ND	0.20	1.40	0.10	0.545	0.010	0.535	0.105	1.13	0.0270	0.050	3.03	0.520	5.45	0.203	0.104
1a-5	5.01	ND	0.23	2.17	0.10	0.531	0.020	0.571	0.053	4.25	0.0181	0.130	1.13	0.330	11.33	0.331	0.323
2-1	5.15	ND	1.72	2.03	0.32	1.280	0.051	1.230	0.083	0.031	0.0220	0.11	4.30	0.503	2.703	0.103	0.294
2-2	5.03	ND	1.52	3.01	0.07	1.240	0.005	1.235	0.040	0.051	0.0148	0.101	3.55	0.421	5.02	0.251	0.273
2-3	5.33	1.20	3.27	4.01	0.24	1.770	0.0	1.770	0.123	0.730	0.0253	0.270	4.63	0.333	3.70	0.131	0.442
2a-1	5.71	ND	0.15	3.32	0.30	1.200	0.0	1.200	0.159	1.20	0.0256	0.030	3.13	1.120	2.37	0.214	0.373
2a-3	5.03	ND	1.31	1.30	1.07	1.470	0.020	1.450	0.065	1.80	0.0134	0.170	3.42	0.370	5.01	0.127	0.110
2a-4	5.03	ND	1.55	1.33	1.03	0.530	0.040	0.490	0.034	6.63	0.0184	0.230	2.72	0.521	12.54	0.222	0.173
3-1	5.15	ND	0.23	1.35	0.07	0.820	0.015	0.805	-	1.38	0.0154	0.110	4.11	0.340	6.53	0.247	0.132
3-2	5.03	ND	1.40	15.77	0.04	0.450	0.040	0.410	0.049	2.01	0.0256	0.10	4.82	0.510	8.13	0.103	0.214
3a-1	5.51	ND	1.40	23.67	0.01	0.495	0.165	0.331	-	1.87	0.0252	0.120	5.52	0.526	10.32	0.212	0.252
3a-2	5.01	ND	1.40	23.28	ND	0.555	0.030	0.255	-	2.39	0.022	0.070	4.50	0.541	5.50	0.133	0.112

* [illegible]

[illegible]

TABLE 4. Total Chemical analyses of tailings from Marmora and Bancroft, Ontario (%, except P = % × 10^{-4})

Sample	Depth	K	Na	Ca	Mg	Mn	Fe	Cu	Zn	P
1 - 1	0 - 1	0.125	0.373	13.755	4.329	0.175	15.27	0.069	0.010	6.51
1 - 2	1 - 2	0.069	0.368	13.685	4.813	0.173	13.13	0.148	0.013	2.35
1 - 3	20-30	0.101	0.359	14.277	4.924	0.179	12.69	0.059	0.012	2.35
1 - 4	30-80+	0.113	0.490	12.849	4.154	0.138	14.67	0.131	0.014	2.17
1a- 1	0 - 1	0.123	0.395	13.374	4.461	0.219	13.70	0.052	0.012	7.30
1a- 2	1 - 3	0.133	0.373	14.301	4.733	0.212	14.30	0.044	0.016	5.39
1a- 3	3 -15	0.118	0.395	15.192	5.051	0.207	12.29	0.040	0.012	1.27
1a- 4	15-42	0.148	0.347	14.326	5.073	0.193	12.38	0.041	0.014	7.21
1a- 5	42-100+	0.133	0.499	13.730	4.390	0.189	19.91	0.062	0.011	3.74
2 - 1	0 - 5	0.165	0.516	13.045	6.292	0.211	11.30	0.033	0.022	11.20
2 - 2		0.145	0.449	11.891	4.892	0.217	11.80	0.037	0.024	2.35
2 - 3	50+	0.157	0.540	13.052	6.219	0.256	14.21	0.065	0.031	2.77
2a- 1	25-55	0.133	0.364	14.967	6.017	0.213	11.09	0.042	0.022	4.49
2a- 2	24-53	0.203	0.397	13.197	5.312	0.233	12.82	0.046	0.056	5.13
2a- 3	55+	0.174	0.280	13.164	4.057	0.180	19.27	0.063	0.014	0.27
3	1 - 2	0.143	0.512	13.846	5.542	0.171	12.00	0.022	0.012	0.27
3	50-60	0.133	0.422	10.911	4.572	0.162	11.15	0.035	0.011	3.04
3a	0 - 2	0.103	0.452	13.770	5.638	0.174	3.01	0.023	0.012	3.30
3a	50-55	0.127	0.411	10.172	4.249	0.148	8.66	0.039	0.014	5.52
4F	1 - 5	1.727	3.279	4.635	1.405	0.091	3.67	ND	0.008	3.14
4F	5 -15	1.777	3.459	4.477	1.151	0.091	4.24	ND	0.012	3.04
4	1 - 5	1.645	3.515	4.640	1.265	0.100	4.18	ND	0.010	3.74
4	40-51	1.496	3.249	5.163	1.747	0.116	5.46	ND	0.016	2.17
5 - 1	1 - 6	1.753	2.561	2.931	1.010	0.056	3.39	ND	0.006	7.21
5 - 1	6 -10	1.978	2.444	2.732	1.771	0.049	2.92	ND	0.005	3.04
5 - 2	11-23	1.559	3.721	3.276	1.416	0.083	3.97	ND	0.003	3.74
5 - 3	23-46	1.622	3.782	3.274	1.462	0.091	4.50	ND	0.024	3.74
5 - 4	48-63	1.400	3.557	3.240	1.296	0.083	5.13	ND	0.018	5.13
6 - 1	1 -10	1.577	3.130	3.574	1.907	0.091	4.26	ND	0.013	3.34
6 - 2	10-27	1.514	3.394	3.457	1.399	0.083	4.40	ND	0.008	2.35
6 - 3	27-35	1.352	3.521	3.657	1.667	0.083	4.32	ND	0.007	3.14
6 - 4	35-51	1.467	3.512	3.591	1.415	0.083	4.75	ND	0.009	5.32

ND = not detected

SESSION III-A

PLANTS IN RECLAMATION

Ms. J. Hanson - Chairman

HIGHWAY RIGHT-OF-WAY REHABILITATION IN NORTHERN ONTARIO USING NATIVE SEDGES

K.W. Dance and D.F. McQuay, Gartner Lee Associates Limited
Markham, Ontario
and
J.E. Gruspier, Ministry of Transportation and Communications
Downsview, Ontario

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ABSTRACT

During the summer of 1982, Gartner Lee Associates Limited investigated the feasibility of permanently establishing native sedges on dry, infertile, sandy, erodible roadside slopes in northern Ontario for the Ministry of Transportation and Communications. Biophysical data were collected at three problem sites, where sedges had colonized roadside slopes.

Literature research and communication with botanists were initiated to address such critical issues as environmental requirements and reproductive strategies of sedges found in the study area. Tolerance of sedges to herbicide application and salt spray was considered as part of the evaluation process.

This preliminary study concluded that certain sedges appear promising enough to warrant further research.

This paper briefly describes elements of a three-phased approach designed to determine whether sedges can be successfully established as a revegetation agent, on barren, infertile soils using conventional seed application methodologies.

INTRODUCTION

On conventional 2:1 slopes composed of coarse textured soils hydroseeding of grass and legume mixtures has failed to establish permanent vegetation cover along highways in northern Ontario. These "problem sites" are characterized by a lack of top soil. Often germination occurs but seedling establishment is poor.

Extensive areas of exposed soil along roadsides are aesthetically unpleasing. Erosion can reduce soil fertility and deposition of soil in watercourses is recognized to have negative impacts on aquatic communities (Dance 1981). Deposition of eroded soils in roadside ditches creates maintenance problems, while eroded soil deposited around trees on private land has resulted in damage claims being made against the Ministry of Transportation & Communications.

As noted by Bradshaw (1983) the challenge before us is to use existing knowledge and innovation to reclaim problem sites.

We have observed in Ontario and elsewhere that certain sedges grow on extremely dry, infertile sites. Cotton grass, a member of the sedge family, has been found to colonize and produce above-ground biomass equal to that of undisturbed tundra on sites where seeding of exotic grass had failed (Chapin and Chapin 1980). Certain sedge species are known to be halophytic (Catling and McKay 1980) and thus tolerate road salt. These observations and characteristics of sedges lead us to explore the merits of sedges for use in revegetating specific types of problem sites where routine methods and special treatments have failed.

OBJECTIVES OF THE STUDY

Research conducted in 1982 was designed to accomplish the following four tasks:

1) determine from existing knowledge whether sedges known from Ontario possess traits which recommend them for use as revegetation agents by R.O.W. managers;

2) determine which species of sedge have naturally colonized specific problem areas;

3) determine, in a qualitative manner, the types of chemical/physical conditions which sedges tolerate at the problem sites;

4) evaluate the findings of 1 through 3 to determine

whether the use of sedges in highway right-of-way rehabilitation appears to be feasible.

STUDY METHODS

A. CHARACTERISTICS OF "IDEAL" SEDGES:

A list of traits required by sedges capable of successful establishment on problem sites was prepared as a means of focusing the research effort. Table 1 contains the list of six key criteria which were researched. Personal communication with experts and literature research were the principal methods used to determine what is presently known about characteristics of sedges occurring in Ontario.

TABLE 1 CHARACTERISTICS OF "IDEAL" SEDGES

1. Must be able to become established and flourish on "problem" sites following introduction by standard inexpensive techniques and equipment, e.g. hydroseeding, without benefit of special site preparation or after-maintenance.
2. Produce a heavy seed crop which is easily harvested and possesses a high germination rate; characteristics which would make seed source development economically attractive.
3. Growth habit is spreading and dense so that a mat of sedges rather than clumps results.
4. Species is plastic in the range of site and climatic conditions which it can tolerate.
5. Is resistant to salt spray and herbicides currently used on roadsides.
6. Has low potential for becoming a "pest" species.

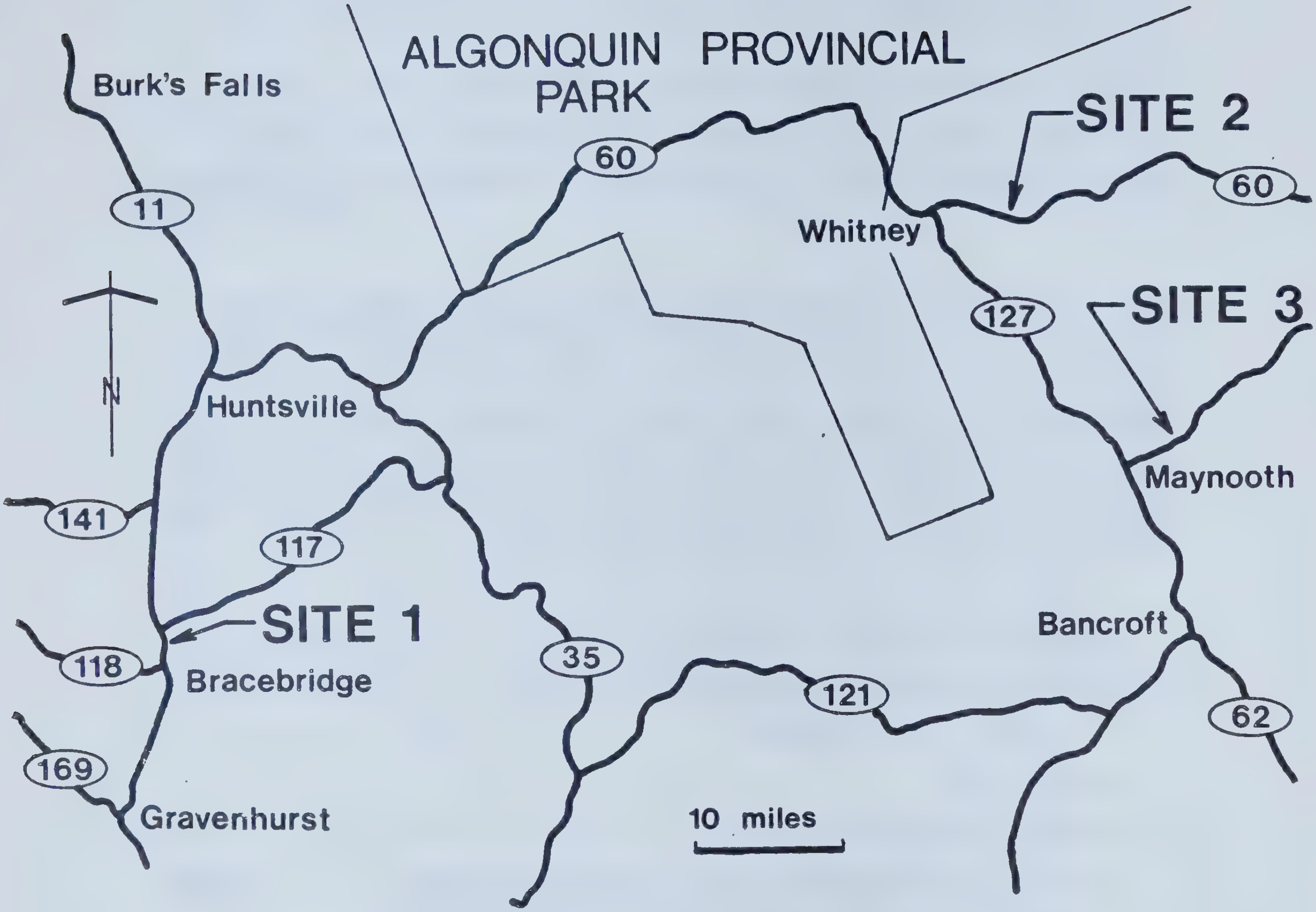
B. SITE STUDIES

Field observations were made to determine the species of sedges which were growing at problem sites and to document conditions at sites which sedges had colonized.

During a reconnaissance trip, a number of sites were visited in northern Ontario. Three sites were chosen for detailed study. Locations of those sites are shown on Figure 1. On August 12, 1982 sites were field mapped, photographed and described. Qualitative information was collected for the following factors:

- site treatment history
- slope angle and aspect
- extent of erosion
- soil pH
- soil texture
- soil fertility
- soil temperature
- percentage of site vegetated
- plant species present
- percent cover contributed by dominant plant groups

FIGURE 1 - Study Site Locations


ALGONQUIN PROVINCIAL PARK
Burk's Falls
11
60
Whitney
SITE 2
60
127
SITE 3
Maynooth
N
Huntsville
141
117
SITE 1
118
Bracebridge
35
121
Bancroft
62
169
Gravenhurst
10 miles

C. EVALUATION OF POTENTIAL OF SEDGES

The evaluation process was subjective and involved reviewing the findings and comments of other experts in conjunction with the results of our field studies. To determine whether any sedges possess potential for success, findings were compared with our original list of criteria to be met by the "ideal" sedge.

FINDINGS:

A. CHARACTERISTICS OF SEDGES:

Literature research and personal communications indicated that all criteria would be met by at least some sedges but that little is known about many members of the sedge family and few species have been researched thoroughly enough to conclude that a single species or even a group of species fulfill every criterion.

Findings will be discussed on a criterion by criterion basis in the order in which they are arranged in Table 1.

1. GROWTH UNDER EXTREME CONDITIONS: The sedge family, Cyperaceae, is one of the largest plant families and hence contains members which flourish in a broad range of environmental settings.

In the present study we concentrated on dry, infertile sites. There are numerous sedges which range through Ontario growing in sandy or rocky areas and along roadsides (Roland and Smith 1969). Unpublished observations of others and our field results indicate that natural colonization of disturbed sites by sedges occurs in Ontario. Chapin and Chapin (1980) report that complete colonization of disturbed Alaskan tundra was achieved by a sedge without benefit of human assistance. Whether sedges sown by hydroseeding will be effective is yet to be determined, as is the need for associated maintenance.

2. SEED CROP: We were only able to obtain information on relative seed crop size through personal communications. In general, there appears to be at least two reproductive strategies in the *Carex* sedges. Certain species possess well developed rhizomes and spread vegetatively. *Carex lucorum*, shown in Figure 2, is an example of such a species. *C. aenea*, which produces large amounts of seed, does not spread by its roots (Crins pers.comm.).

Apparently little is known about germination success in sedges growing in Ontario. Dorph-Petersen (1924), working in Denmark, found that percent germination of several *Carex* species in the first spring ranged from 39 to 98. However, Winterhalder has not had great success with germination of *C. aenea* in experimental native plant mixes in Ontario (pers.comm. 1982).

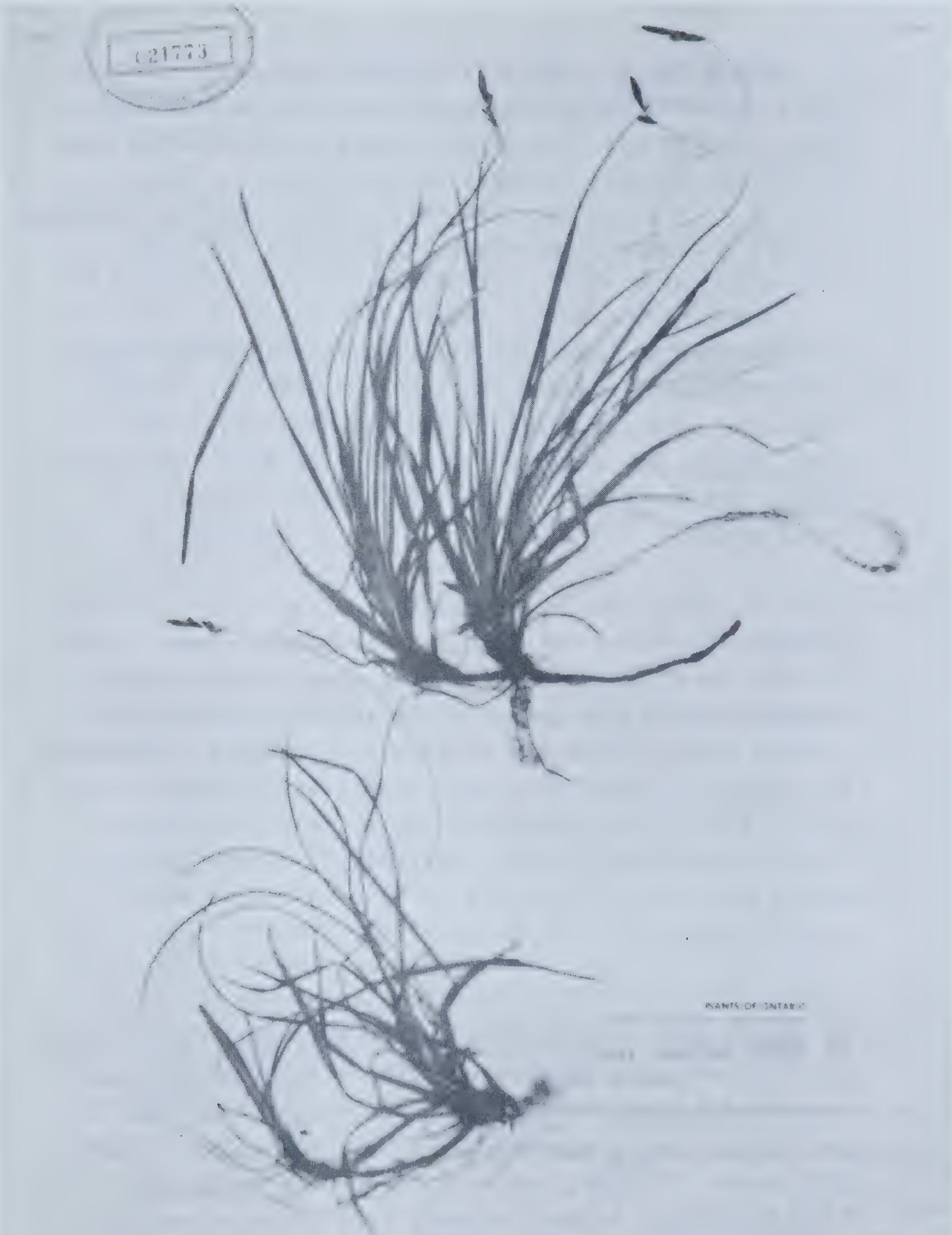

121773
PLANTS OF ONTARIO

FIGURE 2: SPECIMEN OF CAREX LUCORUM. NOTE RHIZOME.

3. GROWTH HABIT: There is a range of growth habits among the many *Carex* species which occur in Ontario. *Carex lucorum* has been observed to form both dense mats and clumps (Crins, Winterhalder pers.comm.). Other species form loose mats and still others, such as *C. aenea*, possess a clumpy growth form.

4. PLASTICITY: There is evidence that many species can tolerate some variation in climatic conditions since they grow across a range of latitude and longitude. *Carex aenea*, for example, is found from Newfoundland to Alaska and south to New York and Montana (Roland and Smith 1969).

Species of concern in this study are those which inhabit acidic, xeric (dry) sites. *Carex aenea* occurs in dry, shaded or open locations (Roland and Smith 1969), including sandy ridges and roadsides (Voss 1972). Similarly, *C. lucorum* is found on sandy, open sites including roadsides, but it can tolerate light shade such as under Jack pine or aspen (Crins pers.comm.). These xeric species may not be suitable for use on slopes where seeps occur.

5. RESISTANCE TO SALT SPRAY AND HERBICIDES: Salt tolerance of candidate species would have to be tested, but those sedge species found growing along the margins of our study sites presumably have been subjected to some salt spray. Catling and McKay (1980) indicate that C. *praegracilis* is particularly salt tolerant and has been found growing adjacent to highways in Ontario.

Sedges are thought to be as resistant to herbicides applied to control woody vegetation as grasses are (Switzer, Robertson, pers.comm.).

6. LOW "PEST POTENTIAL": In the opinion of Stewart of Agriculture Canada (pers.comm. 1982) there appears to be little likelihood of a weed problem occurring if *Carex lucorum* were introduced for roadside reclamation purposes. Evaluations of other species would have to be made on an individual basis.

B. SITE STUDIES

Detailed descriptions of the three sites shown on Figure 1 were recorded on August 12, 1982. It was found that these sites represent a range of densities of colonization by vegetation although site conditions are generally similar.

PHYSICAL/CHEMICAL CONDITIONS: All sites were on 2:1 slopes having sandy, dry, acidic soils, with little or no top soil. Soil texture became more coarse from site 1 (fine sand) through site 2 (medium sand) and contained coarse sand with some gravel at site 3. Erosion of the slopes occurred at all three sites but was more evident on the fine textured soils. Table 2 summarizes physical/chemical conditions at the three sites in a general way.

TABLE 2: PHYSICAL/CHEMICAL CONDITIONS

Slopes:	2:1
Soils:	Sandy, droughty Infertile Acidic Warm Eroded
Area of Sites:	0.6 - 0.17 ha

SITE TREATMENT: Table 3 describes the history of site treatment.

TABLE 3: SITE TREATMENT HISTORY

SITE	TREATMENT	YEAR
1	• Fertilize • Seed grass + legumes • Rye cover crop • Straw mulch & asphalt emulsion	1975
2	• Fertilize) • Seed) • Rye Cover) • Straw Mulch)	1968 repeated in 1969
	• Mugho pine seedlings	1970,1980,1982
3	• Fertilize) • Seed) • Rye Cover) • Straw Mulch)	1969
	• Mugho pine seedlings	1970,1980,1982

NOTE: Standard MTC mix consists of: 55% Creeping Red Fescue, 22% Kentucky or Canada Blue Grass, 12% Perennial Rye Grass, 5% Red Top, 3% White Clover, and was applied at a rate of 80 pounds/acre.

The age of these slopes varies from 8 to 14 years. Existing vegetation communities are described below.

EXISTING VEGETATION: Figures 3 and 4 illustrate the vegetation cover at sites 1 and 2 respectively. Conditions at site 3 resemble those at site 2 except that dense Mugho pine growths are surrounded by bare sand and little else.

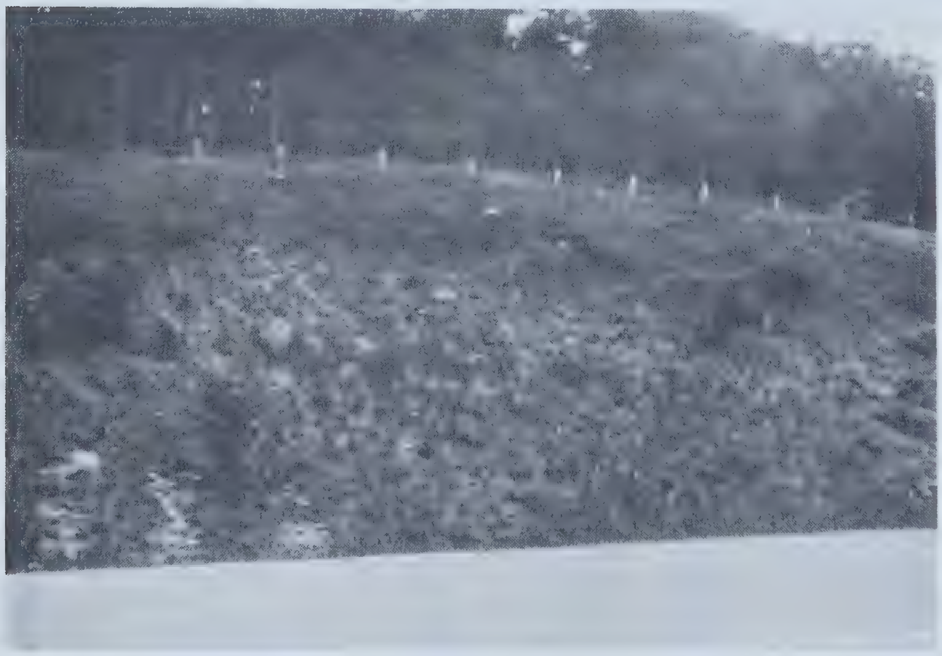


FIGURE 3: CONDITIONS AT SITE 1.

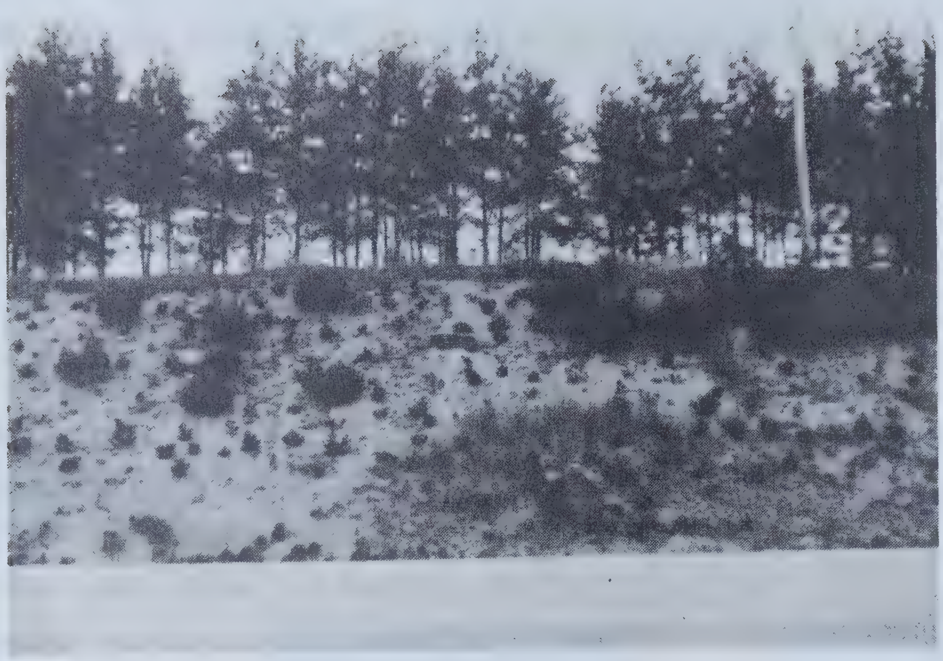


FIGURE 4: CONDITIONS AT SITE 2.

Table 4 summarizes findings of the vegetation surveys. Plant species had colonized each site from wild stock on adjacent areas. Grass and legume species which had been seeded in the 1960s and 70s were essentially absent.

TABLE 4: EXISTING VEGETATION

FACTOR	SITE NUMBER		
	1	2	3
Number of Vascular Plant Species	34	20	10
Number of Sedge Species	5	2	2
Percentage of Site Covered by Sedges	5-10	5	3
Percentage of Site Vegetated	95	20	50

Sedges covered less than 10 percent of each site. At site 1, where vegetation colonization had been most successful, 5 species of sedges occurred. Four of these sedge species were unique to site 1. At sites 2 and 3 only *C. aenea* and *C. lucorum* were present (Table 5).

TABLE 5: SEDGES PRESENT AT STUDY SITES

SEDGE	PRESENT AT SITE(S)
Carex aenea	1, 2, 3
C. arctata	1
C. communis	1
C. houghtoniana	1
C. intumescens	1
C. lucorum	2, 3

Figure 5 shows clumps of C. lucorum growing at site 2. Mats of sedge were present at the top and bottom of slopes at sites 2 and 3.

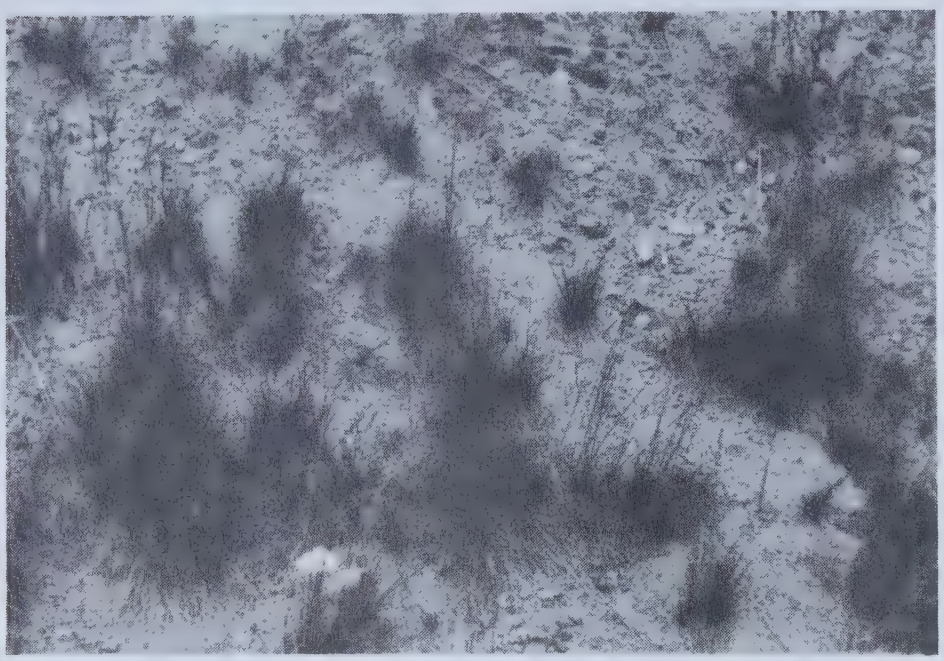


FIGURE 5: CLUMPS OF CAREX LUCORUM GROWING AT SITE 2.

C. EVALUATION

Since C. aenea and C. lucorum were found most commonly in the study area their potential is evaluated in greatest detail. Comments regarding each of the six criteria in Table 1 follow.

- Six different species of sedge had colonized problem sites. Whether any of these species could be established by hydroseeding is unknown.

- *C. aenea*, found at all of our study sites, is thought to produce a heavy seed crop. The germination rate of this species is unknown although Winterhalder (pers.comm.) has found that germination of this species in native seed mixes is poor.

- At certain sites *C. lucorum* formed a mat (Figure 5); this species spreads by rhizomes (Figure 2) which have soil binding capability.

- Both *C. aenea* and *lucorum* grow across northern Ontario.

- Species of sedges growing on the "problem" sites have been exposed to salt spray from the adjacent highway.

- Agriculture Canada has indicated that *C. lucorum* has little potential for becoming a pest.

Less is known about the other four sedge species found at our study sites; nonetheless, these species and others may be capable of stabilizing dry, sandy slopes when introduced by man.

CONCLUSIONS FROM PHASE I

Two basic conclusions can be drawn from the Phase I Study, these are:

1) sedges hold promise as an agent for revegetating "problem sites"; and

2) a number of critical questions remain to be answered before final conclusions on the feasibility of using sedges to solve this problem can be reached.

WHAT NEXT:

The next step is to design and conduct experiments which will test the use of certain sedges on problem sites in Ontario. To accomplish this, the following tasks would be involved:

- Choice of species to use in the experiments;
- Collection of seed for experimental tests;
- Layout of plots on typical problem sites;
- Sow plots with sedge seed at various intensities using conventional techniques e.g. hydroseeding, fertilizer and mulch;
- Sow grass and legume plots and set up "control" plots;
- Compare results among treatments by monitoring the plots for several years.

This approach will provide data with which to develop strategies for the use of sedges as a revegetation agent on problem sites.

It is important to note that several commercial seed companies have expressed interest in developing a sedge seed stock if the next phase of experimentation proves that use of specific sedges will be successful.

Although seeding is thought to be the most economical method to use on extensive problem sites, transplanting sedge clumps or mats may also be feasible where cheap labour is available and the areas being rehabilitated are small.

ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of a number of experts who shared their knowledge of sedge biology with us. John Sewell, Terrestrial Biologist, formerly with Gartner Lee Associates Limited, undertook the Phase I Study. Input from R. Dell of the Ministry of Transportation and Communications is appreciated.

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MEADOW FOXTAIL
IT'S USE FOR RECLAMATION AND CONSERVATION AREAS

KARL FIANDER
OTTO PICK & SONS SEEDS LTD.

ABSTRACT

Meadow foxtail (Alopecurus pratensis), a native of Europe, has assumed greater importance in recent years as a hardy forage grass and lends itself well to the needs of certain reclamation areas. Since its introduction in North America about 1750 it has escaped the cultivated areas and can now be found growing in waste places from Labrador to British Columbia. Its unique qualities make Meadow foxtail well adapted to Canadian conditions. Due to its palatability, it could be of value for areas destined to be returned to agriculture. Harvesting problems prevent its widespread use at present but programs are in place to make sufficient quantities available in the near future.

INTRODUCTION

Reclamation and conservation of land is serious business. Competition for land in the agricultural areas of Canada is intense and sorting land needs requires input from government and industry sources.

Reclamation involves the recovery and improvement of an area that has been adversely effected by man's activities. Such activities may take the form of aggregate extraction, tailings stabilization, revegetation of pipeline and other construction projects, watershed management, and also the improvement of cropland through proper management and conservation techniques. To be successful, reclamation projects must have clear objectives with an adequate definition of what end-use activities will be.

Activities that require subsequent reclamation operations are often centred in areas that conflict with other activities such as agriculture and recreation. The procedures and materials used in "refitting" the land for alternate use depends on what other use is desirable.

Returning land to agriculture presents particular problems. A deep productive soil may take centuries to produce. The natural terrain and drainage patterns have evolved over thousands of years and are virtually impossible to recreate once disturbed. To remove vast acreages of farmland without plans for recovery is short-sighted, inefficient, and a loss for future Canadians.

The Canada Land Inventory of Soil Capability is a classification system for land according to its inherent potential for agriculture. Class I land, for example, has no serious limitations and one could expect good production of corn, soybeans, cereals and forage. Class VII land has no capability for agriculture. Canada has a very small percentage of Class I and II land which is largely situated in areas of southern Quebec and Ontario. Unfortunately this area is the most densely populated and agricultural use conflicts with other activities. Any activity which reduces agricultural potential results in a narrowing of the range of crop species which can be grown successfully. Accordingly a high priority should be placed on keeping these areas intact since climatic and soil restrictions in other parts of the country preclude transferring production there.

Reclamation of disturbed agricultural areas can, and does involve more than mere facelifts for aesthetic reasons. An intelligent plan, utilizing the best techniques and information can result in the recovery of an area to sound and productive farming.

The most productive land, once disturbed may never regain its former agricultural status but can produce excellent crops of forages or see use as permanent pasture. Approximately 45% of Ontario cropland produces forages which provides a sound base for beef and dairy activities.

Traditionally reclamation seed mixtures have been composed of species used for forage. Kentucky bluegrass, Red fescue, Timothy, Red Top, and the legumes such as White Clover and Birdsfoot trefoil are all common species found in reclamation seed mixtures that were first introduced as forage crops.

The search for improved varieties and new species is endless and has resulted in achievements such as: high protein alfalfa, earlier maturing Birdsfoot trefoil, and a leafy more productive Timothy.

Unfortunately the criteria used in selecting new varieties only partly meet the needs of reclamation personnel, therefore, selection is based solely on trial and evaluation. Although farmers may experience many of the same problems establishing crops on marginal land the two fields are largely separate.

The search for new and perhaps more adaptable species and varieties that meet the needs of the reclamation group is a continuous process. One of the most promising new species that will soon be available for reclamation work is Meadow foxtail (Alopecurus pratensis).

HISTORY OF MEADOW FOXTAIL

Meadow foxtail is native to the temperature regions of Europe and Asia and it is believed that initial cultivation occurred about 1750. Today, it is a popular crop in the high ranges of Europe and Western Russia where it is harvested for hay.

Early European immigrants introduced several species into Eastern North America in the mid 1800's and most probably Meadow foxtail was distributed in this manner. It quickly spread to the Pacific Northwest of the United States where it became an important forage crop. Acreage spread slowly at first since seed was hand-stripped at the rate of 10 lbs/day and was thus at a premium. Its use has spread to several other states and has been used in reclamation work as far north as Alaska.

Most recently it has become very popular in the central area of Alberta where it is seeded for very early pasture. Testing and evaluation of several lines is now progressing in eastern Canada at the Pickseed Research Centre in Blenheim, Ontario and at the University of Guelph.

VARIETY DESCRIPTION

Meadow foxtail is a hardy perennial with short rhizomes and an erect growth habit. The stem is about 36 inches at maturity producing a seedhead that resembles Timothy and several other grasses. The term "foxtail" can be attributed to several weedy grasses including Foxtail barley and Yellow foxtail but is unrelated to these common weedy types.

The leaves are dark green about 1/8 inches wide and smooth.

The seed is enclosed in a fluffy, membranous covering which causes severe harvesting difficulties for standard combines. Seed density is very low, in the range of 6-10 lbs/bushel.

Flowering and the development of seed doesn't appear to be sensitive to photoperiod. In warmer climates where some growth continues during the winter, uneven seed maturation occurs. Seed harvesting in these areas can be inefficient with some seed not yet mature while some shatters during harvesting. Where temperature and moisture conditions arrest growth for the winter period, spring growth and seed production is very uniform.

Meadow foxtail is very winterhardy and is the first of the cultivated grasses to begin growth in the spring. By mid-May it can be 6 inches high in Alberta and ready for grazing while in Ontario it can be close to mature height and heading out. It can tolerate frost in all months of the year making it suitable for high altitute and northern applications.

Long spells of hot, dry weather induce Meadow foxtail to undergo a period of dormancy which is broken when cooler, moist, fall conditions return. Growth is quite vigorous in the fall and the plant remains erect and palatable even during the early winter. This late growth also serves to hold an insulating snow cover.

The leaves and stems are high in sugars and relatively soft making it a sweet, palatable forage. Protein content is similar to Timothy in the 5-10% range.

Seed germination is rapid, taking 5-10 days to emerge but the seedlings are not as competitive as ryegrass until they reach maturity.

Meadow foxtail is adaptable to many soil types from moist, organic peats to dryer clay soils. Although it prefers moist, cool areas excellent stands persist wherever sufficient moisture is available during spring growth.

It has shown excellent tolerance to alkaline conditions growing very well in soils with a ph of 8.5 or more. The upper limit appears to be about ph 9.0 but is influenced by soil moisture.

Certain stands on flood plains of the west coast have shown little effect from submergence in salt water for several hours.

The species is characterized by a high degree of structural and chromosomial variation, consequently one can easily select distinct lines from a population in a breeding programme. Those individuals with superior vigour, disease tolerance, etc are isolated and observed for several years before possible release as a certified variety.

Self-incompatibility or the tendency toward cross-pollination is variable.

Information originating in Russia indicates that Meadow foxtail has a strong tendency to form root nodules infected with an unknown bacteria. One laboratory has claimed that a true nitrogen-fixing capability has evolved, and has been observed on Meadow foxtail.

The seed of Meadow foxtail, because of the light fluffy nature is not suitable for many standard seeding techniques and is not compatible with other seeds present in a mixture. Seed coating has solved this problem by giving the seed more density and a smoother outer surface. The coating is in fact three times the weight of the seed itself and is composed of lime and phosphorus. Although fresh seed is unaffected by the coating, germination does decrease with time and therefore should not be stored in a coated form for more than one year.

SUITABILITY FOR RECLAMATION AND CONSERVATION

Meadow foxtail has certain botanical characteristics that can be exploited by many in the field of reclamation and conservation. Seed production problems in the past have restricted supplies and thus it has been used sparingly. Until recently it was felt that harvesting problems would never be overcome and adequate supplies of a reasonably priced seed would never be a reality.

Canadian engineers have now designed and built a special harvester that is in operation in western seed fields and producing cleaner, less expensive seed in greater quantities.

With greater volumes of Meadow foxtail seed available, the species should increase in popularity.

Rather than displace reclamation species currently being used, Meadow foxtail will represent a new resource 'tool' that will offer growth characteristics not available with other species.

There are several characteristics of interest:

1. Fast germination.
2. Very early spring growth, late fall growth.
3. Temperature extreme tolerance.
4. Adaptability to various soils.
5. Tolerates alkaline and acid conditions.

Also

6. Quality forage and pasture producer.

Current use in Canada has been largely for the establishment of permanent pasture in Alberta where spring growth is grazed in May and rotated throughout the rest of the growing season.

A coal tailings stabilization project in south eastern British Columbia, observed by University of Victoria scientists, reveals that Meadow foxtail performed well in a mixture with the more traditional species, Red Fescue, Canada Bluegrass and Red Top.

Also, several sections of the Alaska pipeline project have been seeded with Meadow foxtail supplied by our affiliate Pickseed West. As the major component of various seed mixtures it has proven to be one of the easiest to establish and most adaptable on the variable terrain typical of pipelines.

The valuable characteristics of adaptability and easy establishment make Meadow foxtail a strong candidate for reclaiming disturbed farmland. Productive class I and II farmland in eastern Canada can be left with poor soil and slope characteristics after non-farming use. In effect this lowers the classification to one that may only be capable of forage or pasture production. Although it may no longer be feasible to grow row crops on the reclaimed land it may hold great potential for permanent cover, pasture species.

The Ontario Government's Foodland Guidelines have outlined which areas should hold a high agricultural priority. In addition operators of pits and quarries are under increased pressure to plan and implement reclamation of the depleted areas. In many cases excavation has produced a shallow water table, making the field prone to flooding. Mineralization may have made ph values erratic. Experience has shown that Birdsfoot trefoil, Canada bluegrass, Timothy and Bromegrass have performed well in revegetation projects. Meadow foxtail shows promise of being more adaptable in the moist alkaline areas.

The priority in revegetation, of course, is the establishment of a permanent, healthy ground cover. A successful ground cover may be the sole objective but where the goal is to return the land to agriculture, particular care must be exercized in selecting the most adaptable varieties but also the most productive.

The next step in progressing from a groundcover to productive farming is the introduction of suitable species for forage and pasture.

It has already been established that Meadow foxtail is adaptable, productive, and palatable but seldom are forages grown as a solid stand in Ontario.

Tests performed at the University of Guelph indicate that Meadow foxtail combined with Leo Birdsfoot trefoil produces more dry matter in the month of May, than any other trefoil-grass mixture. In the United States, foxtail is often combined with alfalfa in irrigated pasture. It isn't so competitive that the alfalfa is crowded out yet produces a high quality hay. Birdsfoot trefoil has been one of the most widely used legumes for reclamation projects due to its adaptability. Foxtail-trefoil mixtures appear to perform well, possibly due to their mutual tolerance of imperfect drainage.

In pure stands Meadow foxtail has shown to be similar in dry matter production to Timothy, Orchardgrass and Bromegrass.

Once established, it can become aggressive and dominate in a mixture with other grasses although this isn't likely to occur unless wet conditions prevail.

The problem of tailings stabilization has usually been approached on an individual basis since the nature of the tailings material and the local climate combine to produce a fairly unique environment. Expert consultation and extensive testing are often required before any degree of success is achieved. Although Meadow foxtail has performed well on one tailings project in Canada, there is little to suggest that any species will have broad acceptability. The tolerance to ph extremes and salinity may prove to be valuable, however little is known about other factors such as heavy metal tolerance.

Soil conservation and watershed management is an important part of the protection and wise use of agricultural and recreational land. Erosion of soil is a natural process occurring in all undisturbed areas. It is, however, in equilibrium with the natural soil-forming process. Cultivation, overgrazing and destruction of shoreline plant communities, contribute to wholesale soil erosion.

Temporary waterways occur when the spring melt releases large volumes of water and can be a great problem on cultivated land.

Soil erosion is a function of water volume and speed, and any efforts to reduce these factors will reduce soil erosion.

Conservation authorities and farmers have made more concerted efforts recently to improve the long-term viability of farm land by stabilizing waterways, streams and ditch banks. The selection of the proper seed mixture in these areas is critical and holds great potential for Meadow foxtail.

Commencing growth well in advance of other grasses allows Meadow foxtail to be in a more vigorous state to resist the spring run off. The erect growth habit may provide more physical resistance to flowing water than varieties such as Red Fescue or Timothy.

Submersion for extended periods will check growth but rarely kill a Meadow foxtail stand. Also it is less aggressive than Reed Canarygrass which is known to plug small streams and grow to an unruly height.

Although grassed waterways should not be disturbed by machinery or grazing cattle, farmers may be more inclined to stabilize these areas if some agricultural value could be derived from them. If required, grassed waterway areas containing Meadow foxtail could provide a productive forage yet its excellent recuperative potential ensures a healthy stand before cold winter temperatures arrest growth.

ESTABLISHMENT

Meadow foxtail can be seeded alone or as a component of a mixture. Alberta pastures are commonly seeded with 18 lbs/acre coated seed in early May. Frequently a nurse crop of barley or oats is included which is harvested in August leaving the pasture ready for grazing in the fall.

Because of the fluffy light nature of the uncoated seed only hand broadcasting or hydroseeding is recommended. The coating adds considerably to the density and allows it to be seeded by all common methods; seed drill, brillion, hydroseeder, etc.

For erosion control applications, the seeding rate should be increased to at least 30 lbs/acre bare or 90 lbs coated in combination with other desirable species.

In most areas of Canada spring and early summer seedings appear to be the most successful. Fall seedings should allow at least 6 weeks for seedling development before severe frosts.

CONCLUSIONS

There are many factors to consider before undertaking a reclamation or conservation project. The eventual success of the project depends on the expert advice received from planners, engineers and agronomists. Sources of information and technology are limited, but growing, as experiences are related to others in the field.

In eastern Canada there is concern over the loss of valuable farm land and what should be done to return disturbed areas to a productive state. Equally as important is the protection and conservation of existing land.

As an agricultural crop, Meadow foxtail serves to lengthen the growing season and produce quality forage while maintaining a dense, permanent cover on delicate reclaimed land. The sweet, palatable growth encourages high intake by cattle.

A pasture may be the first step in returning the land to more specialized production. It prevents any further degradation of the land, and has greater soil and water holding capacity than row crops.

The use of Meadow foxtail in conservation projects may prove to be extremely valuable. As a component of an erosion control seed mixture it is well adapted for use in grassed waterways, and stabilization of streambanks. For areas that serve the dual use of erosion control and forage production, the hay or pasture quality is excellent, yet recuperative potential is good.

Currently Meadow foxtail seed is available in coated and uncoated form in western Canada. Interest in eastern Canada is increasing. The Ontario Forage Crops Committee will test several lines beginning this year for comparative performance.

At Pickseed we are working towards improved seed production and processing to meet anticipated demand. The advantages of this relatively recent addition to the Canadian species selection holds promise for several areas of Canada

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INFLUENCE OF AGRONOMIC GRASS-LEGUME MIXTURES ON THE PERFORMANCE OF COMMERCIAL SOFTWOOD TREE SPECIES USED IN RECLAMATION

P. J. King
Reforestation And Reclamation Branch
Alberta Forest Service
Alberta Energy And Natural Resources
Edmonton, Alberta

ABSTRACT

In Alberta reclamation of industrially disturbed lands has the dual objectives of attaining an immediate goal of soil stabilization while also initiating the process of returning a permanent post-disturbance land use. In some situations these goals may be in conflict to a varying degree. This paper deals with one possible instance where the goals may be somewhat incompatible - the use of grass-legume mixes for soil stabilization in conjunction with the use of commercial softwood tree species for timber production. The results of experiments at two locations in Alberta's Eastern Slopes are presented.

INFLUENCE OF AGRONOMIC GRASS-LEGUME MIXTURES ON THE PERFORMANCE OF COMMERCIAL SOFTWOOD TREE SPECIES USED IN RECLAMATION

1. INTRODUCTION

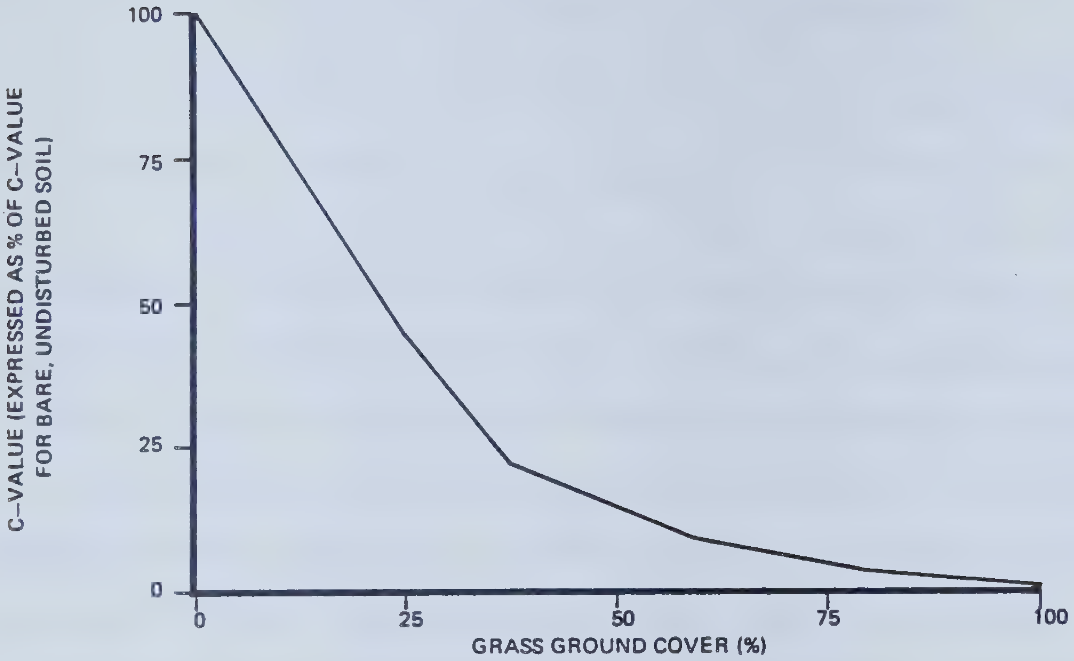
On disturbed, critical sites agronomic grass mixes are necessary to obtain control of water erosion. However, the resulting vegetative cover may be detrimental to attaining a post-reclamation forestry land use. One of the most significant adverse influences exerted by the erosion-controlling grasses may be excessive competition with interplanted trees. Being able to reduce intraspecific grass and tree competition while adequately controlling erosion is a crucial need in meeting both short and long term land rehabilitation objectives. The report herein presents one year's experimental results of two trials which are investigating the competitive influence of selected agronomic grass-legume mixtures on the performance of commercial softwood tree species.

2. LITERATURE REVIEW

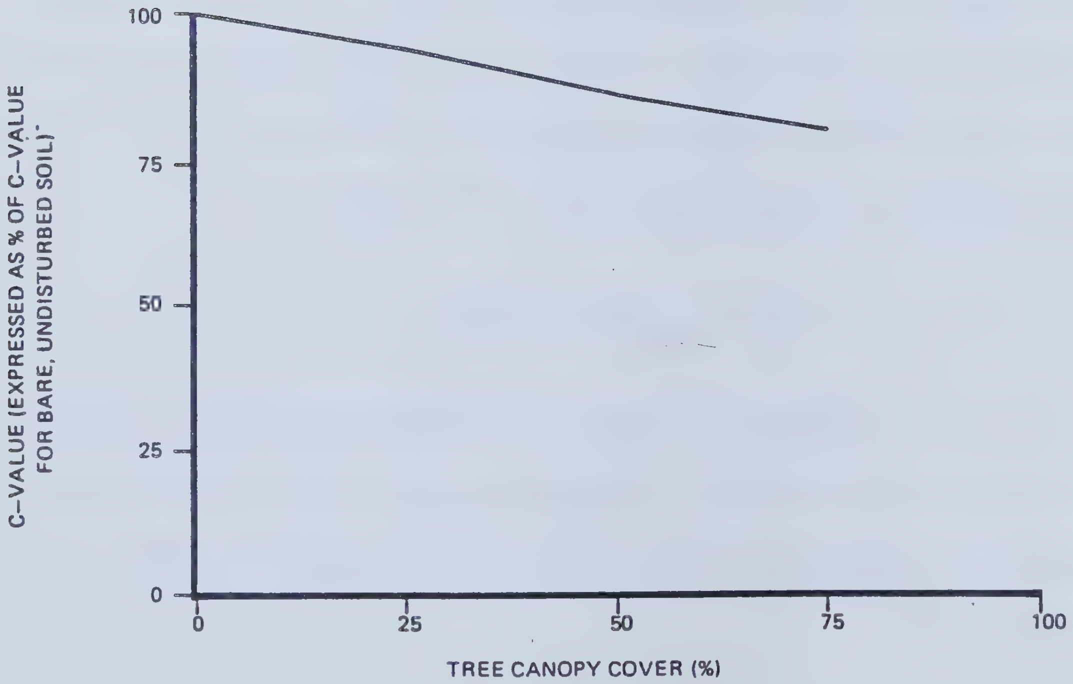
Grasses or grass-legume mixes may be very effective in reducing losses of soil by water erosion. Complete ground cover diminishes erosion to a negligible level while partial covers may substantially reduce soil loss (Figure 1A).

FIGURE 1 — EFFICACY OF VEGETATION COVER TYPES IN REDUCING SOIL EROSION (DERIVED FROM : WISCHMEIER, 1974)

A) GRASS COVER (AT GROUND SURFACE)



B) TREE CANOPY COVER (EFFECTIVE HEIGHT OF 4m, NO VEGETATION AT GROUND SURFACE)



The use of trees alone is inadequate for water erosion control (Figure 1B). On disturbed soils in Idaho, Megahan (1974) estimated that six-year-old ponderosa pine would have to be planted at densities of up to 11,900 trees per hectare to produce a one-third reduction in soil loss: seedling densities which would be both unfeasible and unacceptable for timber management.

While trees must be established in conjunction with ground covers to control erosion, grasses may compete with and cause detrimental survival and growth performance of trees. Ponderosa pine survival was successful when planted simultaneously with grass sowing (Baron, 1962). Tree survival was progressively poorer when planting was carried out during the second and third years after grass sowing. After the third year of this trial, for trees planted simultaneously with grass sowing, pines on ungrassed plots had better survival than when established with orchardgrass, oatgrass, ryegrass or timothy although survival was better on plots sown to bluegrass, wheatgrass, hard fescue or redtop than in ungrassed controls. Baron hypothesized that these differences were possibly due to competition for moisture.

Combinations of grasses and loblolly pine have been used in the southeastern United States (Duffy, 1974). On sandy soils a rapidly developing grass cover reduced pine survival and height growth relative to tree performance in slowly developing covers. The difference in results was not as pronounced on loamy sites. On both soils the use of slowly growing grasses decreased the competition with trees but initially sacrificed ground cover and erosion control. Therefore, seeding mixtures made up to the two grass types may be desirable in combination with tree planting.

In British Columbia, the survival of lodgepole pine was not affected by the density of grass sowing or by the species of grass sown (orchardgrass, timothy, smooth brome, red fescue, hard fescue and crested wheatgrass) while the height growth and biomass of the lodgepole pine seedlings in the fifth year of the study were reduced by high sowing densities (Clark and McLean, 1979). An earlier study had reported that the competitive response of lodgepole pine was independent of soil moisture regime although it was indicated that the survival and growth performance of trees in the presence of competition may have been adversely affected by suboptimum moisture levels (Clark and McLean, 1975).

Studies on white spruce in British Columbia found that white spruce height growth rates were considerably lower in the presence of competition on dry, sandy sites than on intermediate sites (moist, loamy soils) or wet sites (clay or wet, sandy soils) (Eis, 1966). Even though the presence of herbaceous vegetation slowed white spruce height growth rates for several years, it was rarely found to cause significant mortality and failure of regeneration (Eis, 1981).

The preceding partially agrees with the conclusions of Sims and Mueller-Dombois (1968). In soils where white spruce roots were competing with faster-growing vegetation for available water, tree growth can be severely reduced or the spruce may be eliminated altogether.

In Alberta oil sands reclamation research, there appeared to be a relationship between the grass-legume cover, soil moisture content and woody plant (including white spruce) survival on reconstructed soils (Fedkenheuer *et al*, 1980). A relationship was found in the experiment between grass-legume aboveground biomass and woody plant survival although none was evident between cover and survival.

3. METHODS AND MATERIALS

3.1 Experimental Locations

Two experiments have been established. One is at latitude 49°31' N and longitude 114°30' W (Lynx Creek, Southern Foothills) and the other is located at latitude 52°55' N and longitude 116°25' W (Fairfax Lake, Central Foothills), both in Alberta.

3.2 Design

At each experimental site a 2X4X2 factorial experiment in randomized complete blocks was established. Treatments in each experiment included two seed mixtures, four seed mixture application rates and two tree species. Each experimental block was replicated three times. The size of each plot was 5 m X 5 m.

The seed mixture treatments for each of the sites are given in Table 1. The seed mixture application rates on both sites were 0.0, 8.4,

Table 1. Agronomic Species Seed Mixtures Tested At Fairfax Lake And Lynx Creek

Trial	Mixture Designation	Species	% (by weight)	% (by P.L.S.)
Fairfax Lake	I (Edson Mix)	creeping red fescue (Boreal)	40	35
		white clover	20	22
		timothy (Climax)	20	37
		crested wheatgrass	20	6
	II (Bow/Crow Mix)	creeping red fescue (Boreal)	40	20
		white clover	12	8
		timothy (Climax)	24	25
		Canada bluegrass	24	47
Lynx Creek	I (Bow/Crow Mix)	creeping red fescue (Boreal)	40	20
		white clover	12	8
		timothy (Climax)	24	25
		Canada bluegrass	24	47
	II (Blairmore Mix)	creeping red fescue (Boreal)	50	27
		alsike clover	10	7
		timothy (Climax)	20	23
		Canada bluegrass	20	43

16.8, and 28.0 kg/ha (0.0, 7.5, 15.0 and 25.0 lbs/ac respectively). The tree species used were lodgepole pine and white spruce grown from seed of local origin and outplanted as 2-0 bareroot stock and at 1 m X 1 m spacing.

3.3 Establishment

The Fairfax Lake experimental site was prepared in late May 1979, then seeded and fertilized in early July of the same year. The seed mixes were hand broadcast and then lightly raked into the soil. All legume seeds were inoculated with the appropriate *Rhizobium* species immediately before seeding. After seeding, fertilizer was broadcast to supply 61.6 kg/ha N, 17.1 kg/ha P and 16.8 kg/ha S, as determined by soils analyses.

Trees were interplanted at Fairfax Lake in early June of 1980. The seed lots used were lodgepole pine DE 53-21-76 and white spruce DE 51-25-5-75. The trees were hand planted using the "hole planting" technique.

Site preparation, seeding and fertilizing at Lynx Creek were carried out in late June to early August 1979. The site preparation and seeding technique were the same as discussed previously for Fairfax Lake. The analyses-determined fertilizer application rates used were 67.2 kg/ha N and 27.9 kg/ha K. The tree seedlings were interplanted in late May 1980. Lodgepole pine DB 6-4-5-76 and white spruce DB 7-5-5 seed lots were used. The same planting method as described for Fairfax Lake was used.

3.4 Assessments

Grass-legume performance assessments included estimation of total ground cover, total plant density and aboveground biomass. Details on methodology and sampling for the above are given in Table 2.

Tree performance assessments included total height, total diameter and survival. These assessment techniques are outlined in Table 3.

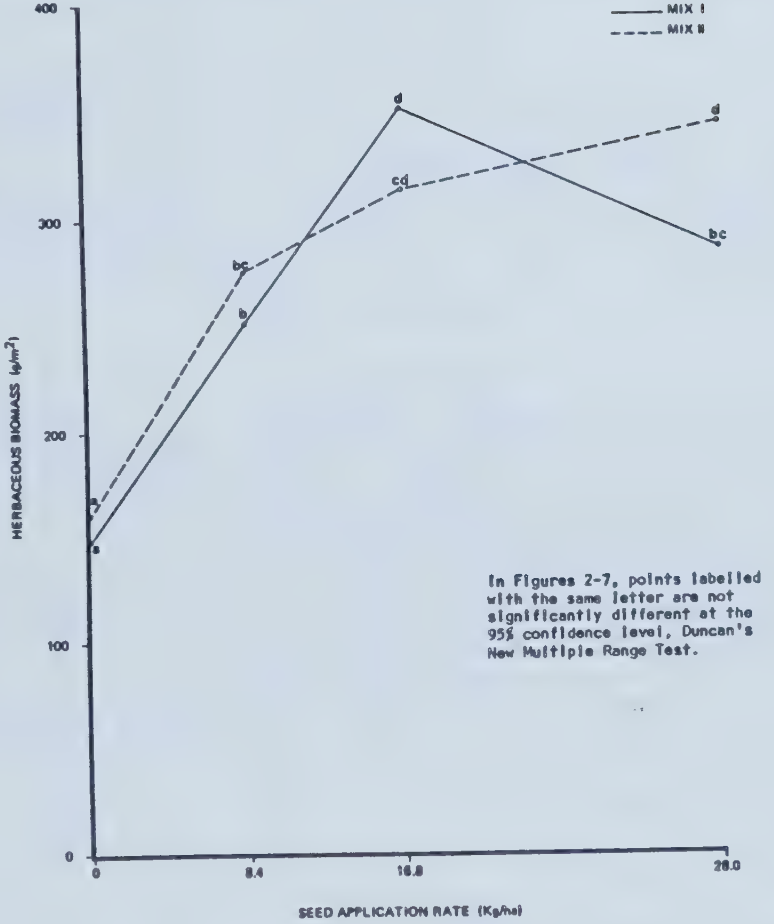
3.5 Maintenance

The 0.0 kg/ha seed application rate plots were mechanically weeded early in the 1981 growing season to minimize the competitive effects of any volunteer vegetation.

4. RESULTS AND DISCUSSION

At the end of 1982 on both the Lynx Creek and Fairfax Lake experiments the effect of seeding rate upon grass-legume aerial biomass was significant. The aboveground biomass levels were generally proportional to the seed mix application rate although the point-to-point differences were not always significant (Figures 2 and 3). Note that the data for tree species has been pooled in these analyses, assuming that the trees have not had an effect to date on grass-legume performance. Also note that volunteer vegetation had occurred in 1982 on the 0.0 kg/ha application rate treatments of both experiments.

FIGURE 2 -
AERIAL BIOMASS AT LYNX CREEK
(1982)



In Figures 2-7, points labelled with the same letter are not significantly different at the 95% confidence level, Duncan's New Multiple Range Test.

FIGURE 3 -
AERIAL BIOMASS AT FAIRFAX
LAKE (1982)

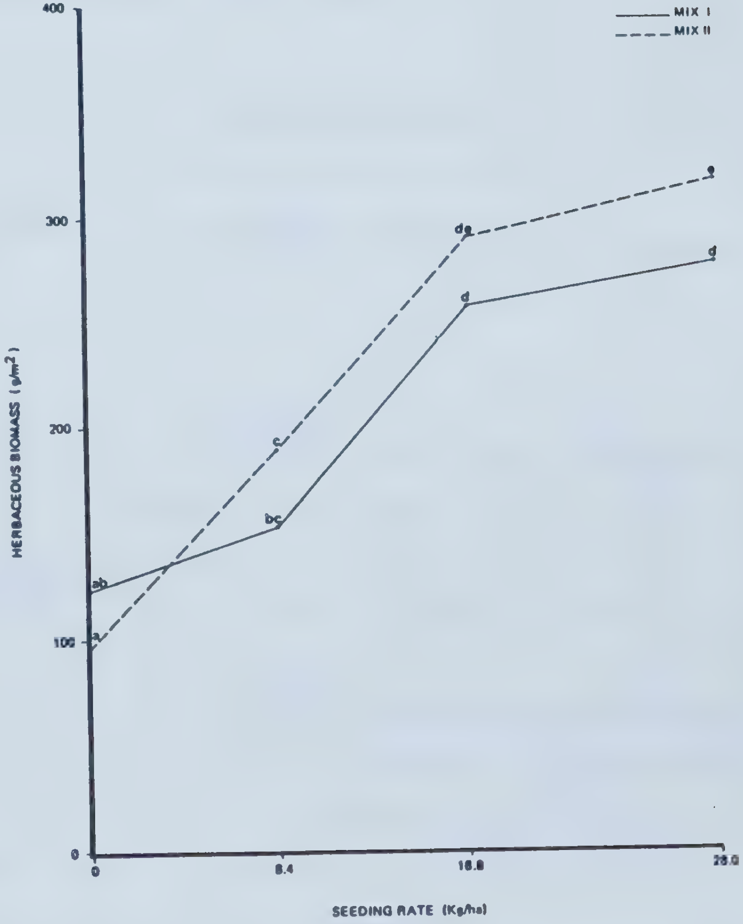


Table 2. Grass-Legume Performance Assessment Methodology And Sampling

Parameter	Methodology	Sampling Intensity
Total ground cover*	Ocular estimate made using a 0.5 m X 0.5 m quadrat with a grid of 100 subplots. Number of filled subplots were counted and the partially-filled were pooled and counted. Cover expressed as the percentage of filled subplots.	Average based on five subsamples per plot.
Total plant density*	Count of number of plants in a 0.25 m X 0.25 m quadrat. Results reported on a 1 m^2 basis.	Average based on five subsamples per plot.
Aboveground biomass* (dry matter production)	Over-dry weight of an aboveground clipping of all living plant materials. Clipping taken at a 1 cm height within a 0.5 m X 0.5 m quadrat.	Average based on five subsamples per plot.

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* Estimate includes volunteer vegetation

Table 3. Tree Performance Assessment Methodology And Sampling.

Parameter	Methodology	Sampling Intensity
Total height	Measurement of the height of each sample tree from the root collar to the apex. Results to be reported as the annual height increment.	Ten permanent sample trees per plot.
Diameter	Measurement of the diameter of each sample trees (2.5 cm above the root collar). Results to be reported as the annual diameter increment.	Ten permanent sample trees per plot.
Survival	A count of the number of living sample trees. Results to be reported as a percentage.	Ten permanent sample trees per plot.

For grass-legume ground cover and density the experimental results were much as described above for biomass. For both seed mixtures on each site, ground cover and density levels were dependent upon and proportional to the rate of seed mix application with no other experimental treatments having been significant (Figure 4-7).

To date survival of pine and spruce seedlings in both experiments has been independent of seed mix and seeding rate treatments. The relationship between seeding rate and tree survival is illustrated in Figures 8 and 9. As discussed previously, Clark and McLean (1979) and Eis (1980) reported that lodgepole pine and white spruce survivals respectively were not normally affected by competition.

At Lynx Creek the effect of the rate of seed mix application on tree annual height increment for 1982 was significant. For white spruce in both seed mixtures and for lodgepole pine interplanted into Mix I the annual height increment was greatest at the 0.0 kg/ha application rate and was suppressed under the higher grass-legume rate treatments (Figure 10). The analysis indicated that for lodgepole pine the height increment of trees planted into Mix I at the 0.0 kg/ha application rate was greater than Mix II whereas no differences were found for the 8.4, 16.8, and 28.0 kg/ha application rate treatments. The difference in lodgepole pine performance between the two application rate control treatments may be due to the amount or composition of the volunteer vegetation. Seed mixture and tree species treatments were not significant in the experiment.

FIGURE 4 -
GROUND COVER AT LYNX CREEK
(1982)

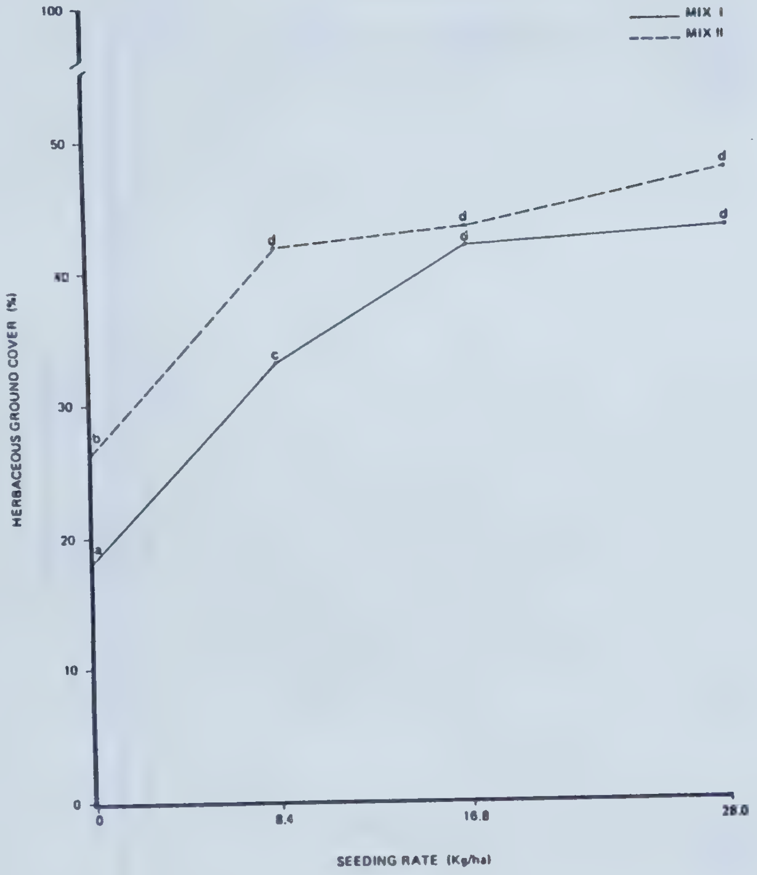


FIGURE 5 -
GROUND COVER AT FAIRFAX LAKE
(1982)

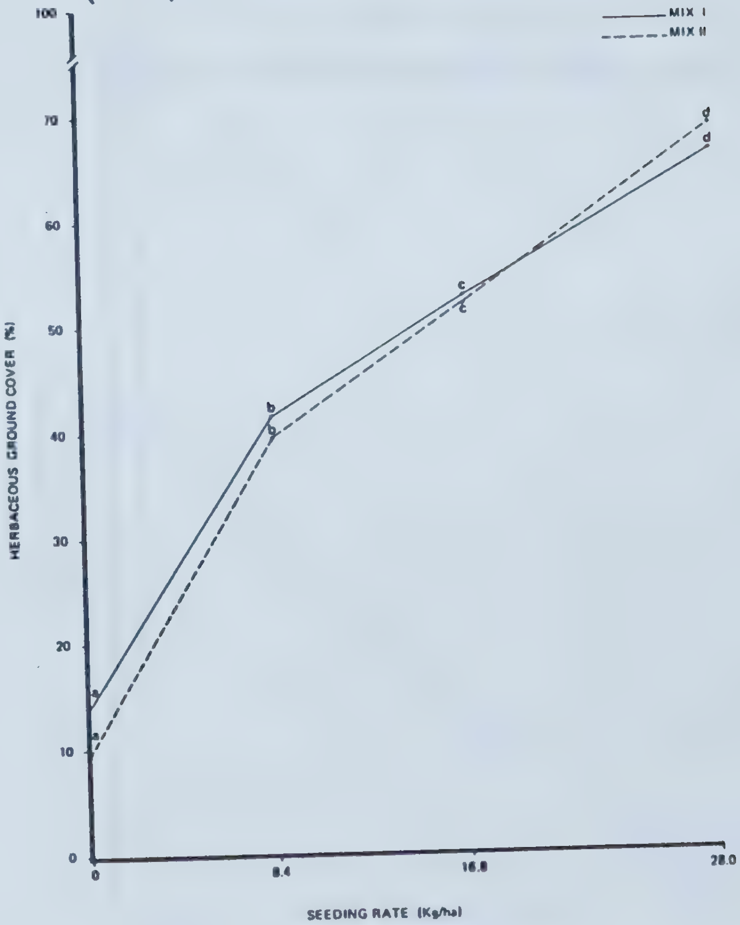


FIGURE 6 -
PLANT DENSITY AT LYNX CREEK (1982)

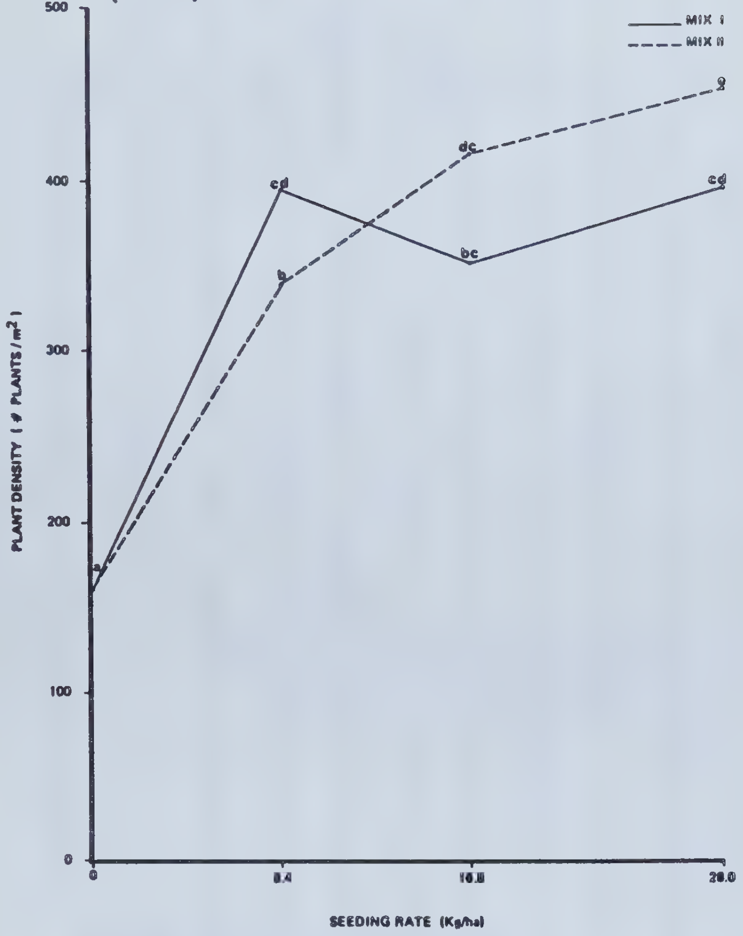


Figure 7 -
PLANT DENSITY AT FAIRFAX LAKE (1982)

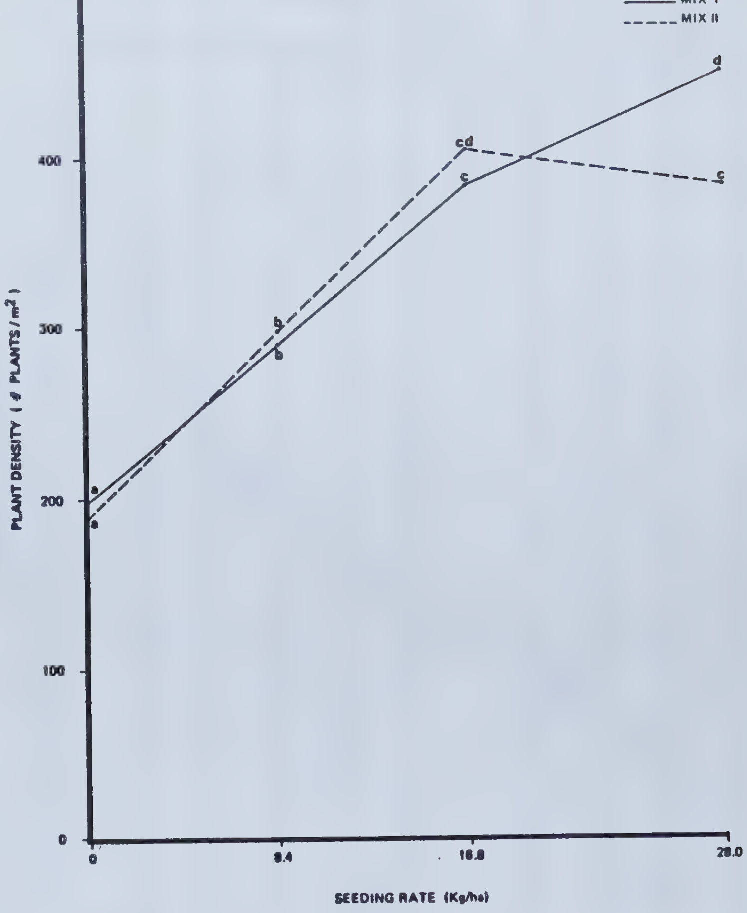


FIGURE 8 -
TREE SURVIVAL AT LYNX CREEK

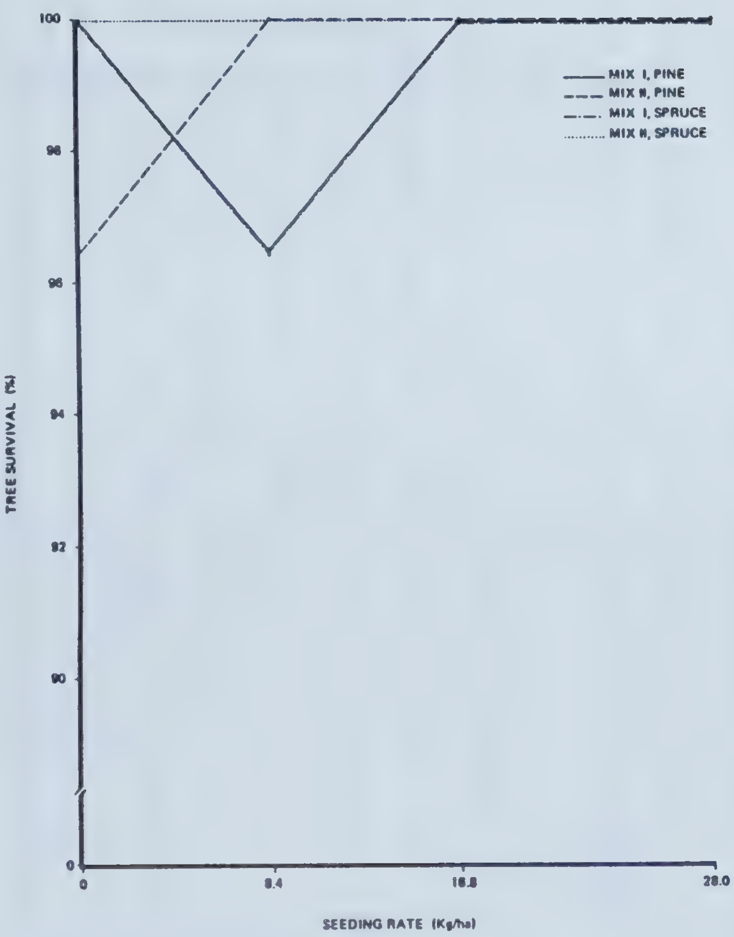


FIGURE 9 -
TREE SURVIVAL AT FAIRFAX LAKE

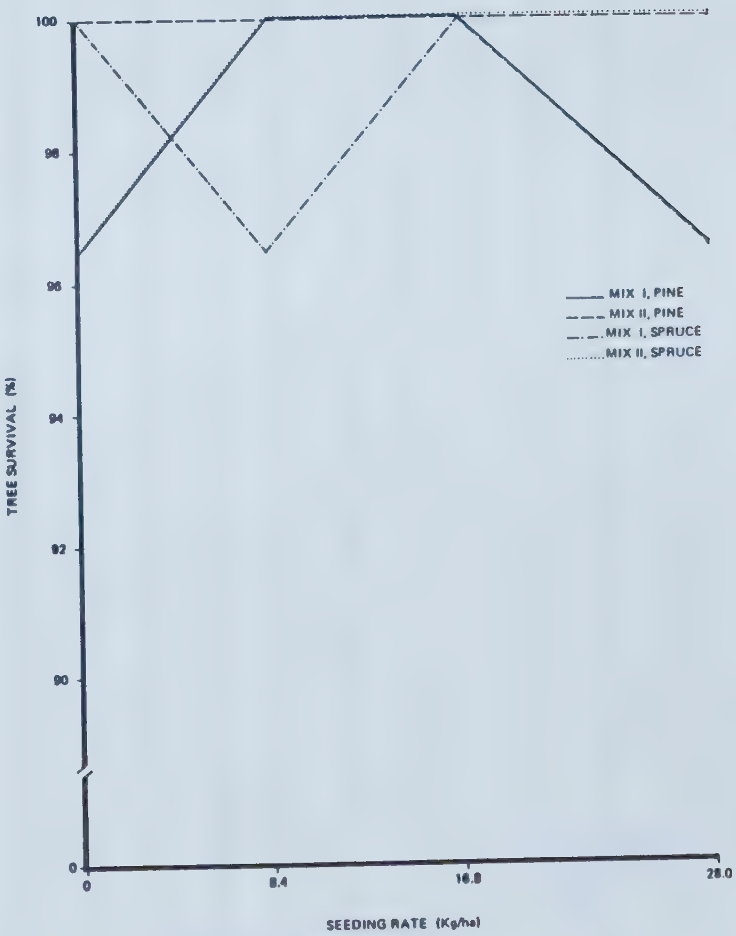


FIGURE 10 -
TREE ANNUAL HEIGHT INCREMENT
AT LYNX CREEK (1982)

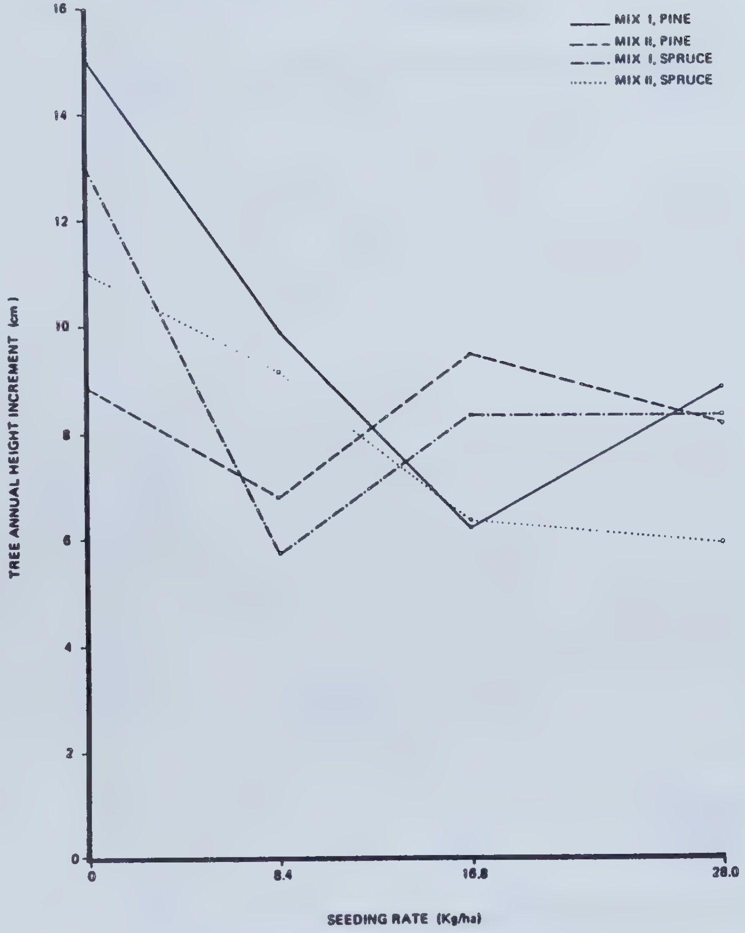
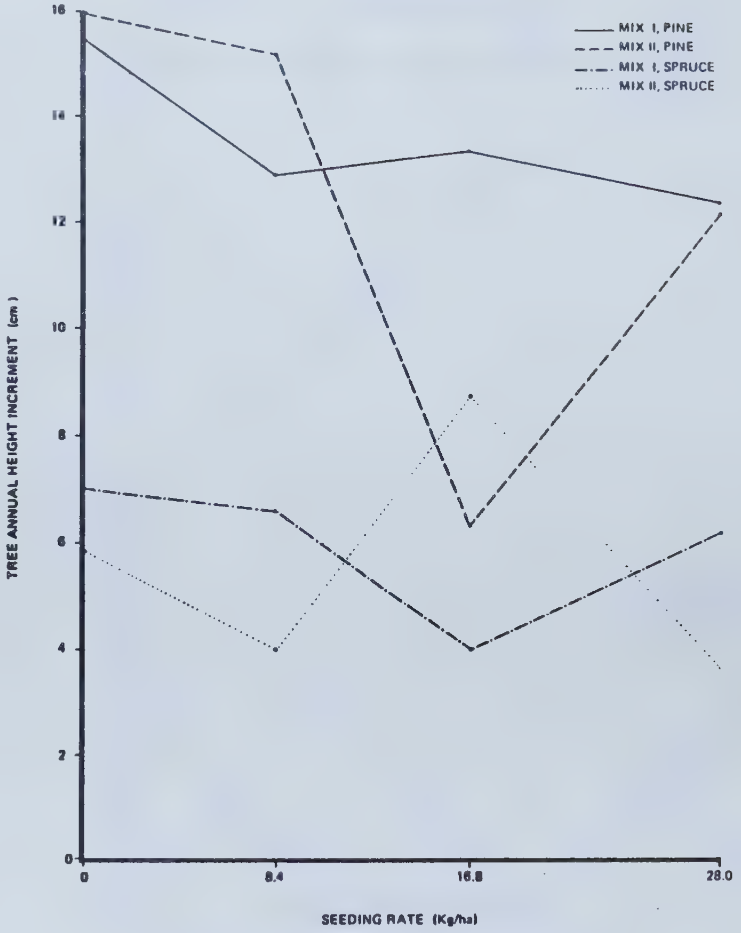


FIGURE 11 -
TREE ANNUAL HEIGHT INCREMENT
AT FAIRFAX LAKE (1982)



At Fairfax Lake the 1982 annual height increment of lodgepole pine was significantly larger than that of white spruce. The height increment at Fairfax Lake was independent of grass-legume seed mix and mixture application rate (Figure 11).

The effect of seeding rate on the 1982 stem diameter increment of lodgepole pine and white spruce at Lynx Creek was significant. For both tree species and grass-legume mixtures, greater stem diameter growth was obtained under the 0.0 kg/ha mix application rate with stem increments being suppressed relatively at greater application rates (Figure 12). No difference was found in the stem diameter growth of white spruce and lodgepole pine when averaged over both mixes for the 8.4, 16.8 and 28.0 kg/ha application rates although the difference was significant in favour of lodgepole pine for the 0.0 kg/ha rate. The data also indicated that for the 0.0 kg/ha application rate, the stem diameter increment of lodgepole pine planted into Mix I was greater than white spruce whereas no difference was found for Mix II.

At Fairfax Lake the annual stem diameter increment for lodgepole pine was significantly greater than that of white spruce. In this experiment the effects of the other treatments were not significant. The diameter growth data is illustrated in Figure 13.

The differences in growth performances between the two sites are noteworthy. At Fairfax Lake, height and diameter increments were tree species dependent while at Lynx Creek growth was largely related to grass-legume application rate. Duffy (1974) and Eis (1966) reported that the

FIGURE 12 -
TREE STEM ANNUAL DIAMETER INCREMENT
AT LYNX CREEK (1982)

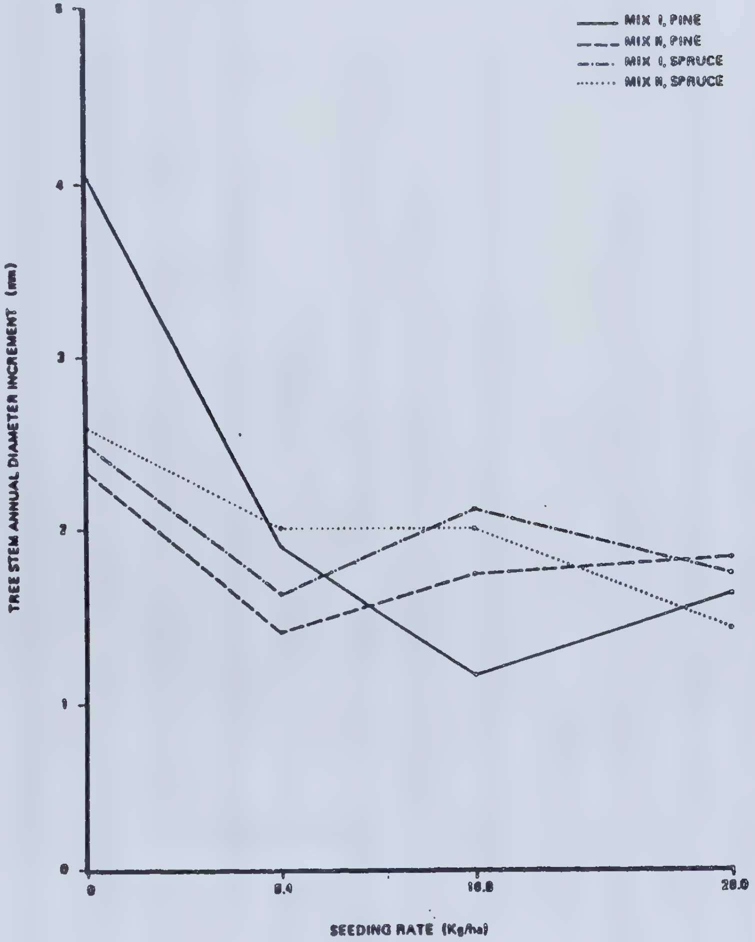
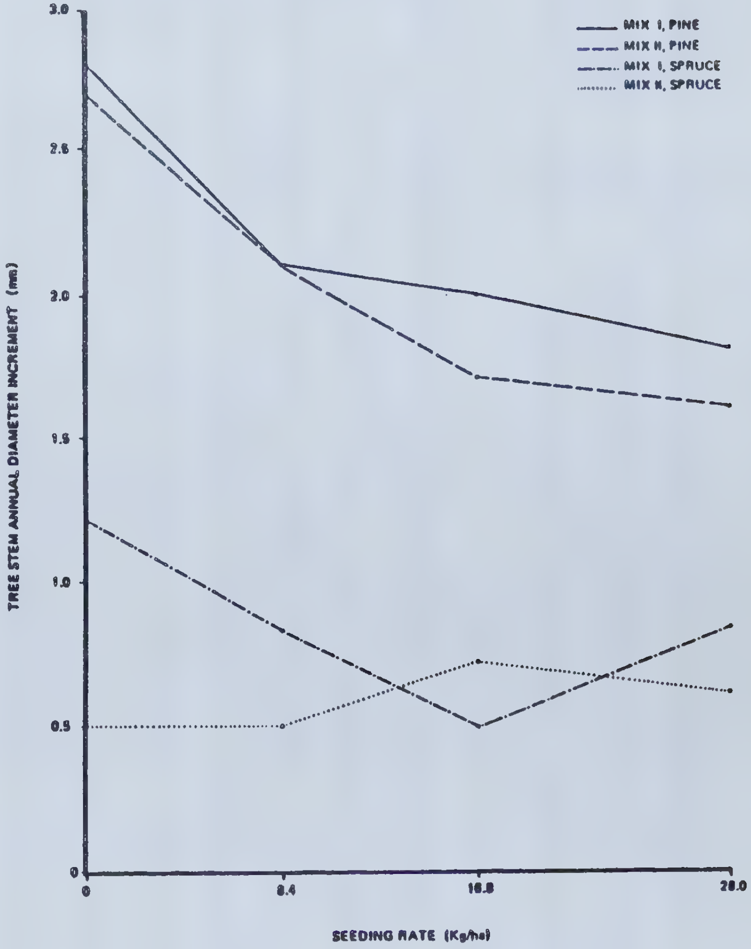


FIGURE 13 -
TREE STEM ANNUAL DIAMETER INCREMENT
AT FAIRFAX LAKE (1982)



performance of woody plants when in the presence of competition may be related to soil texture. Sims and Mueller-Dombois (1968) found that the performance of white spruce was dependent on available soil moisture while Clark and McLean (1975) reported that lodgepole pine may be affected by sub-optimum soil moisture levels. Such factors may explain the respective growth performance of the trees at Lynx Creek and Fairfax Lake. The former is a relatively coarse-textured sandy loam while the latter is a silty clay loam - clay loam. The textural differences between the two sites may lead to varying soil moisture regimes. Site moisture regimes may also partially be a function of climate.

5. CONCLUSIONS

Based on the results for 1982 the following conclusions can be made. First, on both sites the level of the parameters of grass-legume performance were dependent upon and proportional to the rate at which the seed mixtures were applied in 1980. Second, lodgepole pine and white spruce survival has been independent of experimental treatments on both sites. Third, at Lynx Creek tree growth performance was generally affected by the rate at which grass-legume mixes were applied while at Fairfax Lake such differences were not observed. At the latter site tree height and diameter increments were dependent upon tree species. The differences in tree growth performance between the two sites may be related to soil texture, available moisture or precipitation.

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THE POTENTIAL OF SHRUB AND TREE PLANTINGS FOR REVEGETATION AND MANAGEMENT OF SEISMIC LINES NEAR ROCKY MOUNTAIN HOUSE, ALBERTA

by

David J. Downing [1]

Richard D. Revel [2]

and

T. David Dougherty [3]

Abstract

Seismic lines constructed for the purpose of geophysical exploration differ environmentally from adjacent forest communities. In general, on-line communities tend to be moister and sunnier than those of the adjacent forest. These conditions can provide a more favorable environment for the growth of some tree and shrub species that are potentially useful for long-term erosion control, watershed protection, wildlife habitat modification, reforestation, and access control. *Alnus sinuata*, *Salix* spp., *Populus tremuloides*, *Populus balsamifera*, *Pinus contorta* var. *latifolia*, *Picea glauca* and *Picea mariana* are considered as possible candidates for seismic line revegetation. Management recommendations to meet land use goals within the Eastern Slopes area of Alberta are made with reference to field observations, relevant literature, and the current management and policy setting.

1. Environmental consultant, Sunburst Resources Ltd., 1050 Elveden House, 717 7 Ave. S.W., Calgary, Alberta T2P 0Z3.

2. Associate Professor of Environmental Science, Faculty of Environmental Design, University of Calgary. 2500 University Drive N.W., Calgary, Alberta T2N 1N4.

3. Researcher, Faculty of Environmental Design, University of Calgary, 2500 University Drive N.W., Calgary, Alberta T2N 1N4.

1. INTRODUCTION

Petroleum and natural gas are currently two of Alberta's most important resources. Provincial government statistics indicate that petroleum and natural gas production accounted for $15.92 billion in provincial royalty revenues during the period 1976-1981 (Alberta Energy and Natural Resources, Annual Reports, 1976-1981).

Geophysical exploration employing seismic methods is commonly the first step in the search for petroleum and natural gas. Underground explosions or surface vibrations produce sound waves which are reflected from subsurface rock strata and picked up by sensitive surface receivers called geophones. These translate sound waves into electrical impulses which are recorded for later analyses aimed at reconstructing the subsurface geometry and choosing the most promising sites for exploratory drilling (Fig. 1).

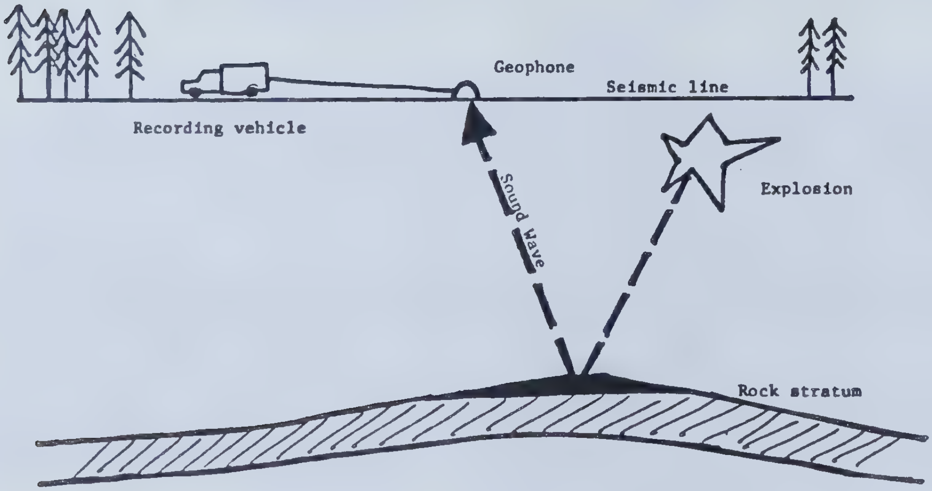


Figure 1. Simplified Seismic Layout

Seismic exploration normally involves the use of large vehicles such as recording trucks. In forested areas, this means that trees must often be bulldozed to allow the movement of vehicular traffic. Seismic lines usually range from 5m-8m wide, may be many kilometres long, and are usually straight. The horizontal spacing between lines varies with the level of geophysical information required and the nature of subsurface structures; for example, in some parts of west-central Alberta where very small subsurface features are drilling targets, seismic exploration can be quite intensive (Fig. 2).

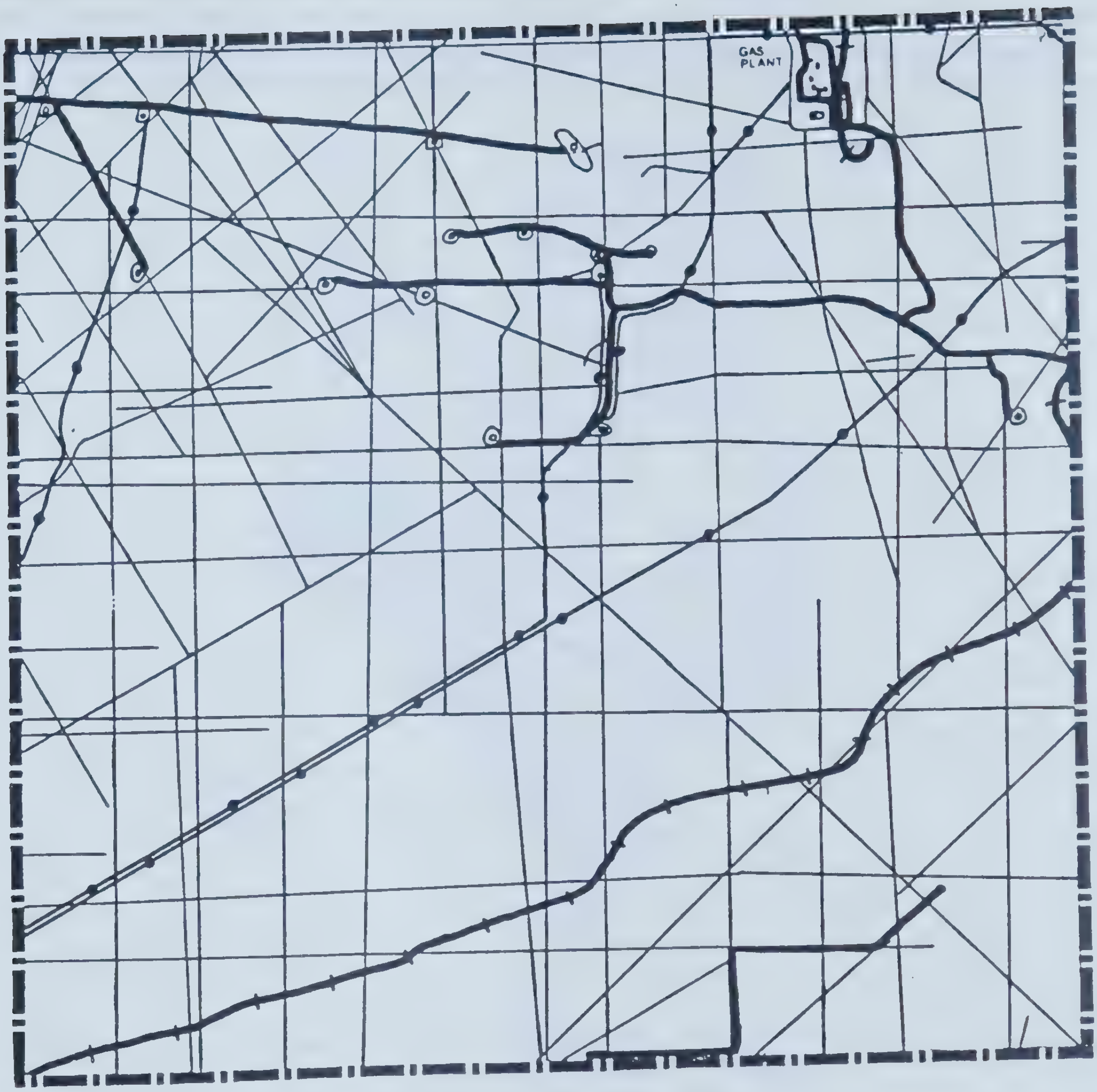
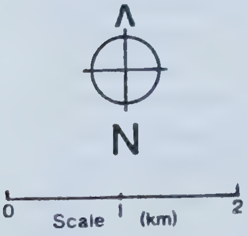


Figure 2. Petroleum-related development in one township near Rocky Mountain House, Alberta (Twp. 37, R9, W5M)

Legend: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Scale
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━━ Roads (including well access roads)

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—— Seismic lines

⊙ Wellsites

▪ Buildings

The clearing of land for seismic exploration accounts for approximately 70 percent of the total land area disturbed by non-renewable resource extraction activities and roads in the Green Area of the Province, a largely forested and non-settled area of Provincial public lands including much of western and northern Alberta (Fig. 3).

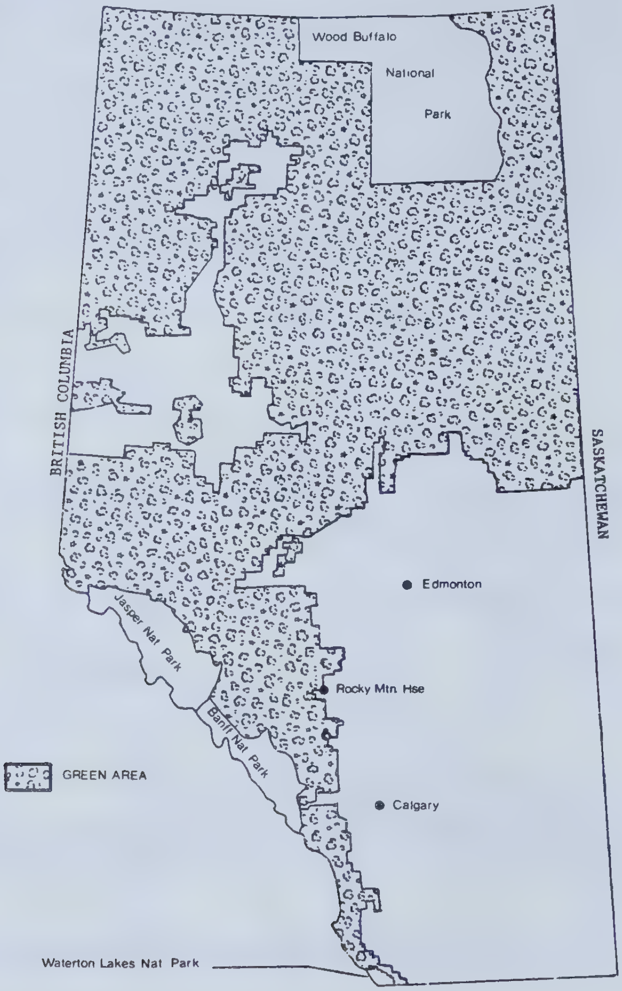

Wood Buffalo
National
Park
BRITISH COLUMBIA
SASKATCHEWAN
Edmonton
Jasper Nat Park
Rocky Mtn Hse
Banff Nat Park
GREEN AREA
Calgary
Waterton Lakes Nat Park

Figure 3. Green Area of Alberta (redrawn from Alberta ENR (1981a) "Alberta Public Lands")

As of 1980 in the Green Area, a total of 219 071ha of land had reportedly been disturbed by seismic exploration (Alberta Energy and Natural Resources, 1981b). The Environment Council of Alberta (ECA) released a report in 1979 concerning the environmental effects of forestry operations in Alberta. In that report, several problems associated with seismic exploration activities were outlined, including soil erosion, stream siltation, wildlife harassment and overexploitation due to increased vehicular access, and timber losses (ECA, 1979).

The concerns raised in the 1979 ECA report and the dearth of published information regarding the ecological effects of seismic lines in Alberta led us to undertake a study to examine the environmental effects of seismic line clearing in the Eastern Slopes region, a forested area of about 70 000 square kilometers rich in both renewable and non-renewable resources (Fig. 4).

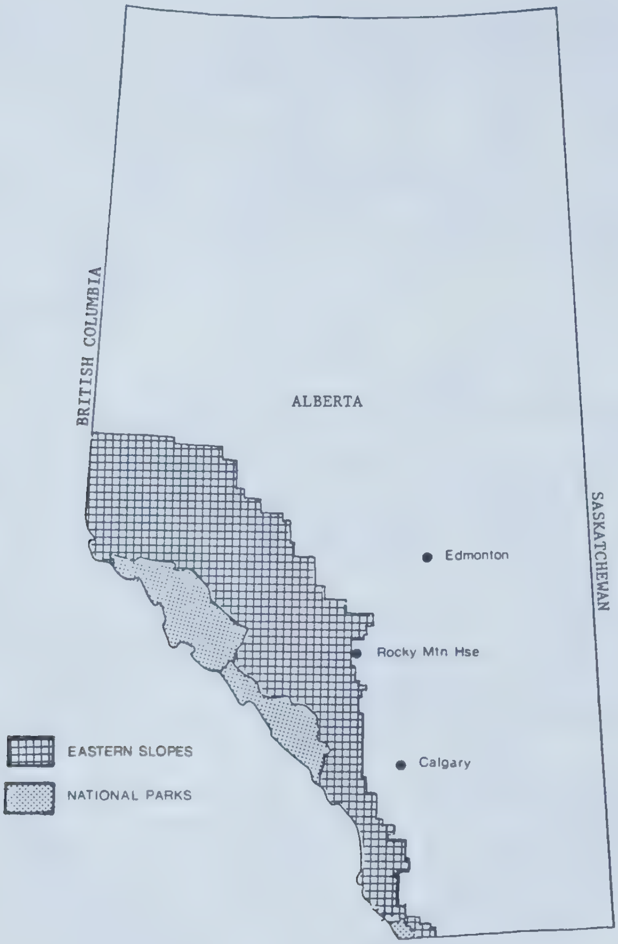


Figure 4. Alberta's Eastern Slopes
(redrawn from Alberta ENR (1977) "*A Policy for Resource Management of the Eastern Slopes*)

The study had two major components - a forest growth component that examined the growth responses of conifers to seismic line cutting, and a revegetation component that examined revegetation trends on seismic lines cut through coniferous forests. A comprehensive report (Revel *et al*., 1983) outlines the main study objectives and gives a full account of our findings.

This paper constitutes a precis of some information presented in the revegetation component of that report. It was prepared in response to a perceived need for a more comprehensive approach to seismic line reclamation than is currently practiced. At present, reclamation is directed toward erosion control through the use of physical erosion control measures, and through revegetation with a grass-legume seed mix. Although erosion control is undeniably a high-priority objective, we believe that some tree and shrub species are also of potential value for revegetating seismic lines and attaining a variety of reclamation goals, including erosion control. The objectives of this paper are therefore to:

1) summarize some of the major findings of the revegetation study carried out by Revel _et al_. (1983) with regard to natural tree and shrub growth on seismic lines in west-central Alberta; and

2) suggest some directions in which seismic line revegetation management might proceed, based upon our findings and the existing policy and legislative framework in Alberta.

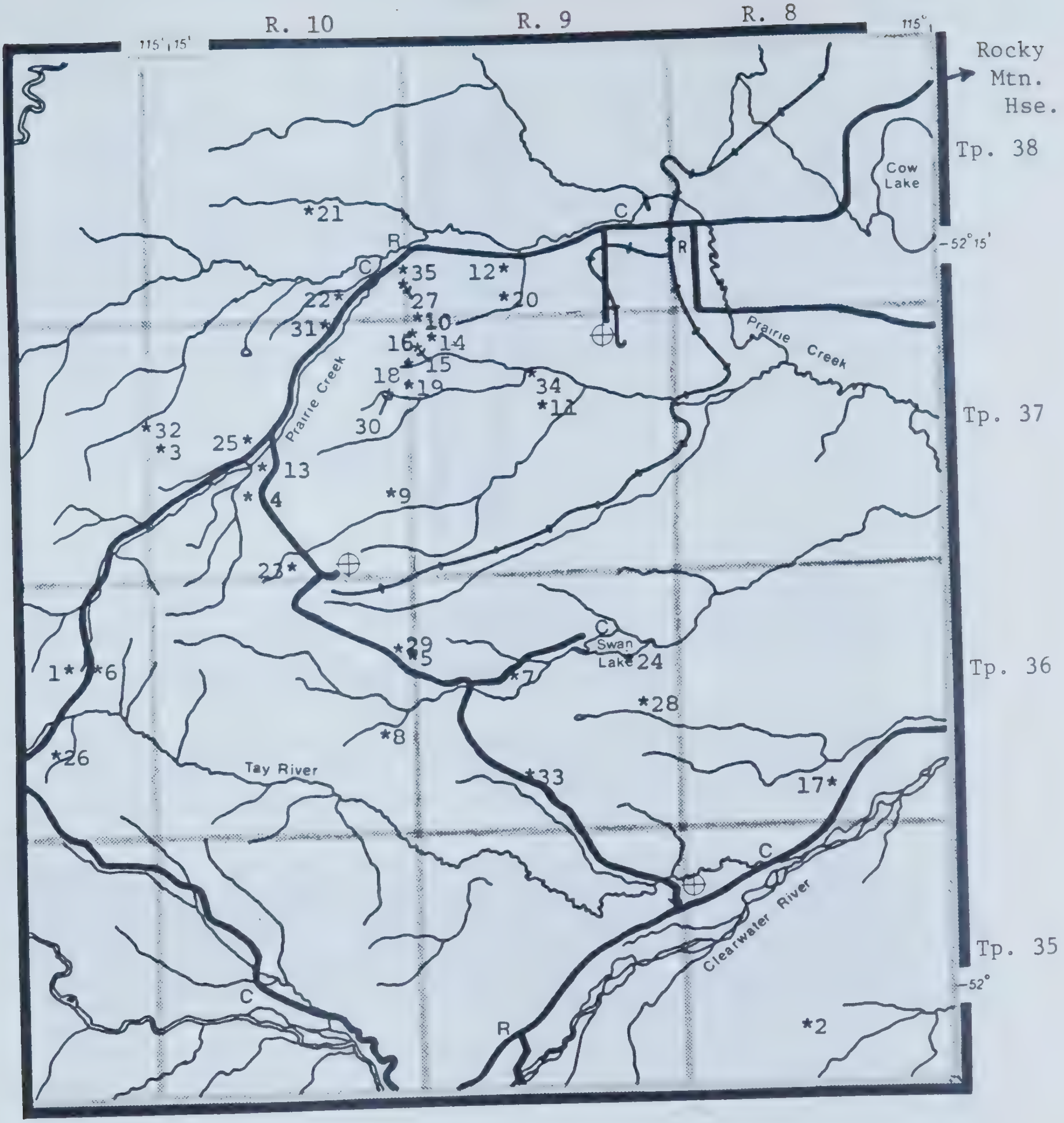
2. STUDY AREA AND METHODS

An area southwest of Rocky Mountain House, Alberta was selected (Fig. 5). It lies entirely within the Eastern Slopes and includes about 14 townships of land (1 290 square km). The area is highly variable with respect to topography, surficial geology, soils and vegetation. Forestry, oil and gas production, and recreation are of considerable significance in the area's economy (Alberta Energy and Natural Resources, 1980, p. 9). The Rocky-Clearwater Forest, which includes the study area, is important for both wildlife habitat and watershed values, and seismic lines are a common landscape feature.

Thirty-four individual study sites with at least three plots at each site were analyzed. One plot was located on the seismic line, and one immediately adjacent to the seismic line along the forest edge. A third control plot was located in the forest at least 20m back from the line to ensure that it was well beyond the influence of the seismic line clearing. All plots were 5m by 20m in size; plot layout is shown in Figure 6.

Site selection was based on a number of criteria (homogeneity of the stand absence of anthropogenic influence other than the seismic line, representation of a variety of stand types, environmental conditions, and seismic line ages and orientations). Most seismic lines had been cleared 10-30 years prior to 1981.

Detailed vegetation analyses were carried out at each plot. All plant species within each plot were documented and the percent cover of each species visually estimated for tree, shrub, herb, and moss strata. Tree seedling counts were conducted in all on-line plots. Site conditions were recorded at each plot, and included slope, drainage class, hygrotope, aspect, parent material and soil type. A relative insolation scale was developed for qualitatively comparing light conditions on seismic lines cut through different forest stands. Other qualitative observations, such as the degree of wildlife use of the lines and apparent recreational vehicle use, were also made.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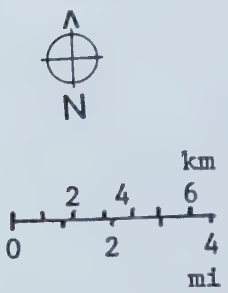
R. 9
R. 8
115°15'
115°
Rocky Mtn. Hse.
Tp. 38
Cow Lake
52°15'
Tp. 37
Tp. 36
Tp. 35
52°
Prairie Creek
Prairie Creek
Tay River
Swan Lake
Clearwater River
C
R
*21
*35
12*
27
*20
22*
31*
*10
16*
*14
15
18
*19
*34
*11
30
*32
*3
25*
*13
*4
*9
23*
*29
*5
1*
*6
*7
24
*28
*8
*26
*33
17*
*2

Figure 5. Study Area

Legend:


N
km
2 4 6
0 2 4
mi

~ Creek or River

⬭ Lake

━ Major road

┿ Railway

⊕ Gas plant

▒ Township boundary

C Campground

R Ranger station

*2 = site location and number

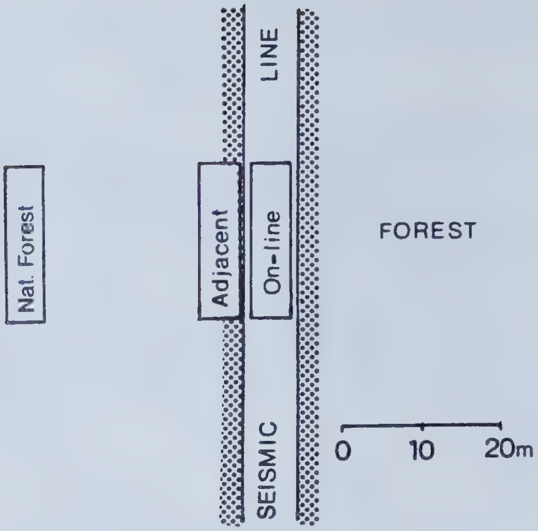

LINE
SEISMIC
Nat. Forest
Adjacent
On-line
FOREST
0
10
20m

Figure 6. Plot Layout

Soil samples were collected at each plot and later subjected to detailed chemical and physical analyses. Quantitative soil chemical data were then compared statistically. Vegetation-environment data were analyzed through tabular comparisons to enable a correlation of successional trends on seismic lines with the vegetation of natural undisturbed forest communities.

3. RESULTS

Several species of coniferous trees and deciduous trees and shrubs were observed to colonize seismic lines. The success of an individual species appears to depend mainly upon the amount of light reaching the seismic line and the moisture status of the line. Post-clearing use of the line by wildlife or humans, and the plant community through which the seismic line was cut, also influence the presence and growth of tree and shrub species to some extent.

3.1 Coniferous Tree Species

1) The principal coniferous species recolonizing seismic lines were lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) BSP, and very occasionally subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.).

2) Species composition on line generally reflects the influence of adjacent stand composition and canopy cover. Conifer regeneration was primarily black or white spruce when forests adjacent to seismic lines had high canopy cover.

3) The majority of seismic lines (23 of 34 sampled sites) had a stocking density in excess of the minimum 800 three-year-old or older seedlings/ha regarded as adequate by the Alberta Forest Service. However, conifer growth was very slow; most regeneration on seismic lines was substantially less than 2m tall, and the tallest tree was a 4m lodgepole pine on a 23 year old line. Shading of seismic lines by adjacent forest stands is thought to be at least partly responsible for slow growth.

4) The distribution of conifer seedlings along seismic lines is generally negatively correlated with both shrub and herb cover, particularly grasses. This observation suggests that competition is also an important factor influencing conifer growth on seismic lines.

5) Pine regeneration on exposed mineral soil was better than either black spruce or white spruce regeneration. With a few exceptions, pine was the predominant regenerating species on drier sites. On moist to wet sites, spruce regeneration predominated.

6) Browse damage by ungulates and snowshoe hares was fairly common on lodgepole pine seedlings but much less common on black and white spruce seedlings.

7) There was very little conifer regeneration on recently cleared seismic lines and on lines where off-road vehicle use had occurred to the extent that trails were clearly visible.

8) The best conifer regeneration was found at locations where seismic lines intersected, suggesting that both the duration and intensity of light is a significant factor controlling regeneration. The larger cleared area of line crossings undoubtedly allows more light to reach the ground than on many seismic lines where the adjacent tree canopy shades the line for part or most of the day. Increased insolation likely produces higher diurnal soil temperatures in clearings than under the forest canopy; increased growth might result, provided that moisture is not limiting.

3.2 Deciduous Tree Species

1) Trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*Populus balsamifera* L.) were the only deciduous tree species noted on seismic lines in the study area. Both were common colonizers on most lines except for those in the subalpine. Trembling aspen occurred more frequently than balsam poplar. The occurrence of either species in adjacent forest understories was uncommon, although both species were sporadic components of the overstory in coniferous forests.

2) Trembling aspen and balsam poplar growth was slow on most seismic lines; heights of less than 2m were usually recorded for these species. However, good growth was noted on those seismic lines receiving high insolation and having moist soils.

3) Good growth of balsam poplar and trembling aspen was also observed at places where seismic lines intersected other lines or clearings, and where insolation was consequently higher.

4) Seismic lines cut through stands where trembling aspen or balsam poplar are present in the tree canopy are apparently good candidates for natural recolonization; root suckering probably occurs along with seed germination.

5) Observations indicated that trembling aspen and balsam poplar were favoured browse species for wildlife.

3.3 Shrubs

Twenty-five shrub species colonized sampled seismic lines in the study area (Table 1). However, not all of these appeared to be of equal importance in natural seismic line revegetation, and in deciding which of these species was likely to be of most use in reclamation, three arbitrary criteria were used:

1) the relative constancy of the shrub in seismic line plots;
2) its observed or reported value as wildlife forage and/or cover; and
3) the availability of published information on the species with which to correlate observations made during this study.

Willows (*Salix* spp.) and Sitka alder (*Alnus sinuata* (Regel) Rydb.) were the shrub species that best met these criteria.

Identification of willows to species was often difficult because of the lack of floral material. However, the few plants from which adequate floral material could be collected indicated that *Salix glauca* L., *S. myrtillifolia* Anderss., *S. phylicifolia* L. ssp. *planifolia* (Pursh) Hiitonen and *S. petiolaris* J.E. Sm. occurred on seismic lines; *S. bebbii* Sarg. is a likely colonizer of seismic lines also as it is reportedly very common throughout Alberta (Watson *et al*., 1980, p. 465). Willows were present on many seismic lines cut through lower-elevation lodgepole pine and lodgepole pine/black spruce stands. In general, moist lines that were not heavily shaded by adjacent stands appeared to produce the best willow growth in terms of percent foliar cover. Willows seemed to be highly favoured browse in the study area.

Sitka alder was observed to occur less commonly on lines than willows. Environmental conditions favouring growth appear to be moderate to high insolation and moderately well-drained, moist, fine-loamy soils. Excellent growth of alder occurred along roadsides and at places where seismic lines intersected with other lines, roads, and wellsite clearings, especially where alder formed part of the adjacent forest understory. Dense thickets in excess of 2m in height were common under such conditions. Sitka alder was lightly browsed in comparison to willows, trembling aspen or balsam poplar.

Table 1. Shrubs occurring on seismic lines in the study area

Species[1]	Occurrence[2]	Conditions[3]	Erosion[4,7]	Wildlife value[5,7] forage/cover	Availabil
Salix spp.*	c (31)	i(l-h); h(vm-m)	++	++/++	+
Vaccinium caespitosum	c (23)	i(l-h); h(vm-m)	?	?/-	?
Rubus idaeus var.* gracilipes	c (23)	i(l-h); h(vm-m)	-[8]	+/+	+
Vaccinium vitis-idaea	c (22)	i(l-h); h(vm-d)	?	?/-	?
Rosa woodsii/ Rosa* acicularis	c (22)	i(m-h); h(vm-m)	++	+/-	+
Rubus pubescens	c (19)	i(l-m); h(vm-m)	?	?/-	?
Alnus sinuata*	c (18)	i(m-h); h(vm-m)	++	+/++	+
Ledum groenlandicum	c (17)	i(l-h); h(vm-m)	?	?/-	?
Ribes glandulosum	c (11)	i(l-m); h(vm)	?	?/-	?
Spiraea betulifolia*	c (11)	i(l-m); h(vm-m)	++	+/-	-
Vaccinium myrtilloides	n (9)	i(m-h); h(vm-d)	?	?/-	?
Lonicera involucrata	n (7)	i(l-h); h(vm)	?	?/-	?
Arctostaphylos uva-ursi*	n (6)	i(h) ; h(m-d)	-	+/-	-
Ribes lacustre	n (6)	i(l-h); h(vm)	?	?/-	?
Viburnum edule	n (6)	i(m-h); h(vm-m)	?	?/-	?
Sambucus racemosa var. melanocarpa	n (5)	i(l-m); h(vm-m)	?	?/-	?
Sorbus scopulina	n (5)	i(m) ; h(vm-m)	?	?/-	?
Shepherdia canadensis*	s (3)	i(m-h); h(m-d)	+	+/-	-
Betula pumila var. glandulifera	s (2)	i (?) ; h(vm)	?	?/-	?
Amelanchier alnifolia*	s (1)	i(l-h); h(m-d)	++	++/-	-
Potentilla fruticosa*	s (1)	i(m-h); h(vm-d)	+	-/-	-
Prunus virginiana*	s (1)	i(m-d); h(vm-m)	++	+/-	+
Vaccinium oxycoccos	s (1)	i(?) ; h(vm-bogs)	?	?/-	?
Vaccinium scoparium	s (1)	i(?) : h(?) (subalpine)	?	?/-	?

---

1. Species nomenclature follows Hitchcock and Cronquist (1973) and Moss (1959). Species marked with an asterisk are discussed in Watson et al., 1980.

2. c= constant (occurring in more than 10 of 34 on-line plots). n= non-constant (more than 3 but less tha 10 of 34 plots). s= sporadic (occurring in 3 or less of 34 plots). Numbers in parentheses indicate total number of plots in which a given species was found.

3. Environmental conditions. i= insolation:i(h)=high insolation; i(m)= moderate insolation; i(l)= low insolation. E.g. i(l-h) means the species occurs under conditions of low to high insolation.

   h= hygrotope (soil moisture): h(vm)= very moist to wet; h(m)= moist; h(d)= dry. E.g. h(vm-m)= very moist to moist sites.

   For constant and non-constant species, the range of light and moisture conditions encountered on seismi lines during the study is reported. For sporadic species, where few environmental observations were ma conditions reported by Watson et al. (1980) are used where available.

4. Erosion control ability (as reported by Watson et al. 1980).

5. Wildlife value. Forage= forage value for various wildlife species as reported by Watson et al., 1980. Cover= large mammal cover value - assigned on the basis of height growth (as reported in Moss, 1959) and growth success (constancy of occurrence) on lines. For example, Lonicera involucrata might provide adequate cover for small ungulates under favourable conditions, but was uncommon on seismic lines and therefore is of little utility.

6. Availability (as reported by Watson et al., 1980)

7. ++ = high rating; + = moderate rating; - = low rating; ? = information unavailable

8. Erosion control value of this species questionable on seismic lines; tended to favour slash and soil piles left after clearing.

4. MANAGEMENT CONSIDERATIONS

The selection of appropriate plant species for reclamation is in part a function of both the ecological requirements of candidate species and the land use objectives for a given land area. We have presented our findings on the occurrence of several tree and shrub species on seismic lines, together with inferences regarding the suitability of conditions for growth, in the previous section.

Land use objectives within the Eastern Slopes region are defined in regional terms by a document commonly referred to in Alberta as the Eastern Slopes Policy. Under this Policy, lands within the Eastern Slopes are zoned into broad land units with specified policies, management objectives and permitted land uses (Alberta Energy and Natural Resources, 1977, p. 3). Seismic exploration activities are subject to the conditions and constraints applicable to zones designated under Eastern Slopes Policy (Alberta Energy and Natural Resources, 1979, p. iii). The objectives and constraints of zones defined by this Policy therefore serve as logical guidelines for the reclamation of lands within the study area.

The study area includes land belonging to six of eight defined zones (Fig. 7), but most of the area falls within the Critical Wildlife Zone or the Multiple Use Zone. The main intent of the Critical Wildlife Zone is to maintain and improve essential habitat for specific wildlife populations. The intent of the Multiple Use Zone is to allow multiple land use and development within a context of watershed and environmental conservation. Off-highway vehicle (OHV) use, petroleum exploration and development, logging, and several other land uses may be restricted within the Critical Wildlife Zone, but such activities are generally under fewer constraints in the Multiple Use Zone.

Other policies also guide activities within the Green Area as a whole. For example, the sustained yield policy of the Alberta Forest Service aims at balancing timber harvest and growth towards a goal of continuous long-term production at sustainable levels. Various Acts also legislate responsibility concerning watershed protection and erosion control.

A number of topical areas concerning seismic line reclamation are addressed below within the context of policy-defined or legislation-defined objectives for the Eastern Slopes.

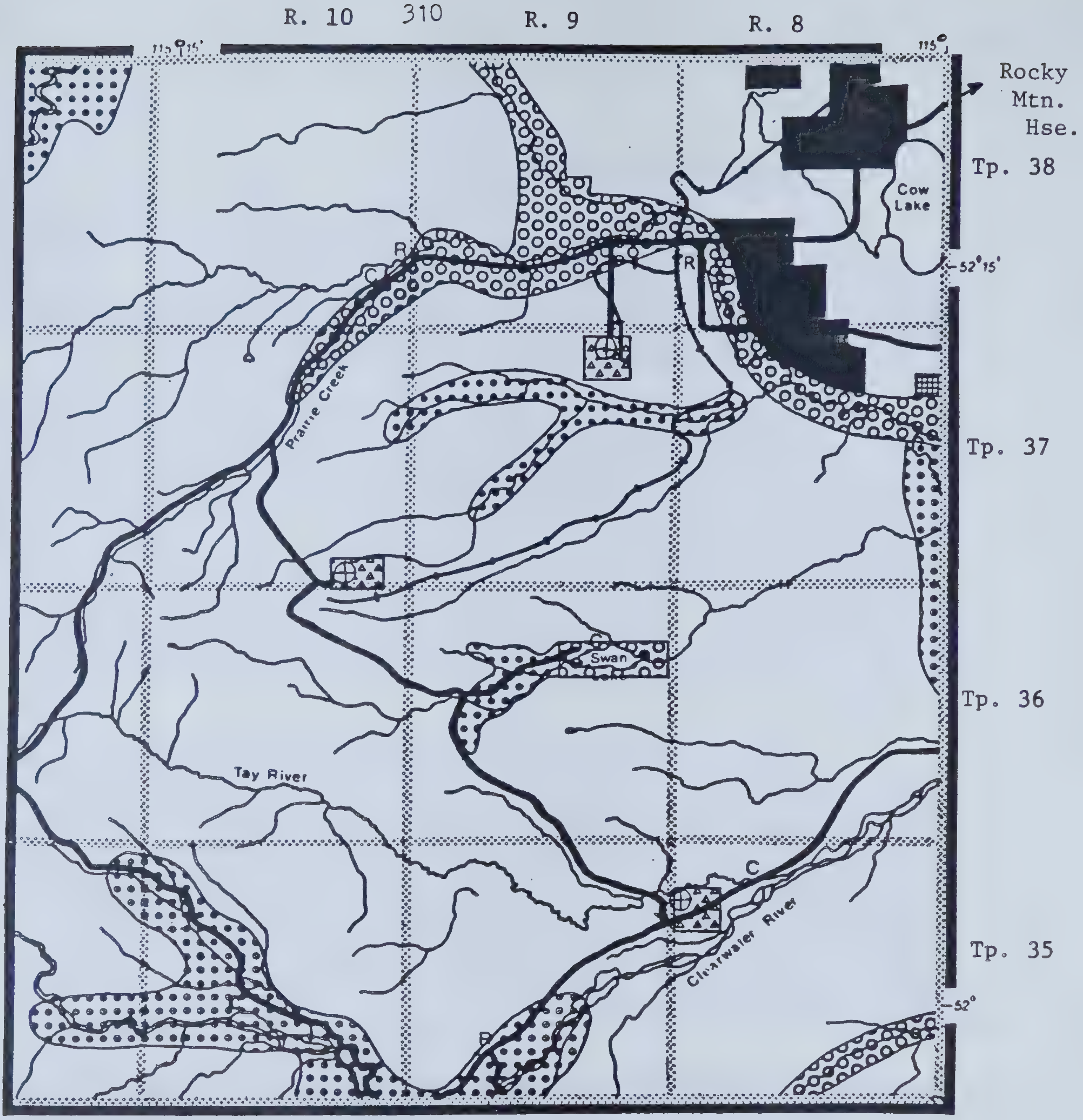
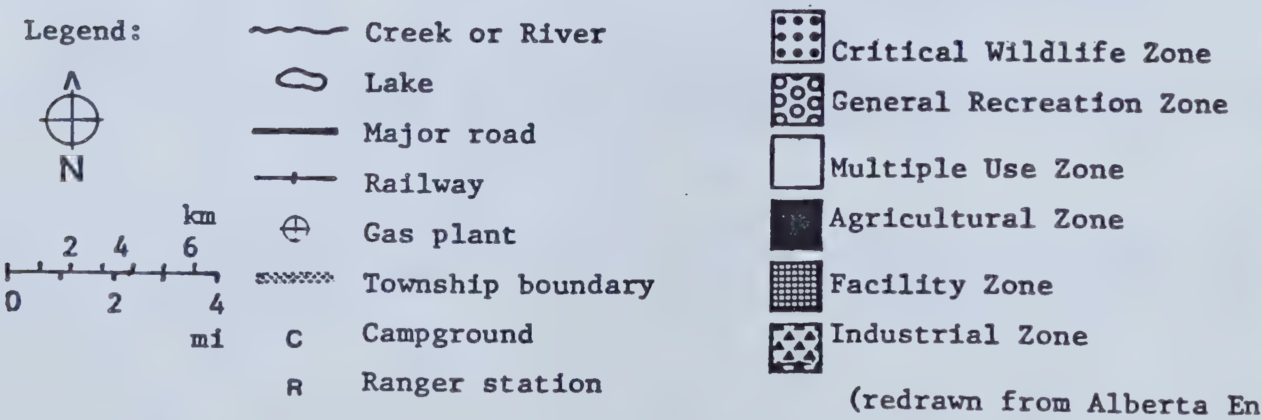

R. 10
R. 9
R. 8
115°15'
115°
Rocky Mtn. Hse.
Tp. 38
Cow Lake
52°15'
R
C
R
Prairie Creek
Tp. 37
Swan
Tp. 36
Tay River
C
Clearwater River
Tp. 35
52°
R

Figure 7. Eastern Slopes Policy Zoning in Study Area


Legend:
N
km
2 4 6
0 2 4
mi
Creek or River
Lake
Major road
Railway
Gas plant
Township boundary
C Campground
R Ranger station
Critical Wildlife Zone
General Recreation Zone
Multiple Use Zone
Agricultural Zone
Facility Zone
Industrial Zone

(redrawn from Alberta Energy and Natural Resources 1977)

4.1 Erosion Control and Watershed Protection

Erosion control and watershed protection are high-priority objectives of Eastern Slopes policy and management. At present, seismic line reclamation is directed primarily toward erosion control and seismic lines are seeded with a grass-legume mixture in combination with physical erosion control measures. Trees and shrubs will undoubtedly be of value in controlling erosion and protecting watershed yield and quality over the long term; however, the present practices seem more appropriate for retarding erosion immediately following clearing, when rapid erosion control is required.

4.2 Coniferous Reforestation

Although reforestation is essential to attaining the sustained yield policy objectives of the Alberta Forest Service, it does not seem appropriate to reforest all seismic lines. Our results suggest that lines cut through older stands which are tall enough to create shady conditions on the lines should probably not be reforested; on-line plantings may not grow quickly enough under such conditions to produce a usable crop by the time surrounding stands are harvested. Lines cut through younger stands are candidates for reforestation. When selecting lines for reforestation, consideration should be given to site quality, insolation, soil moisture, silvicultural techniques (including line treatments such as reseeding), subsequent use of the lines by wildlife and humans, and land use objectives. For example, reforestation of lines that receive OHV use is unwise; time, money, manpower, and planting stock are likely to be wasted unless such use can be controlled (see also Sec. 4.3 below). Similarly, lines cut through Critical Wildlife Zones should probably not be reforested because of the greater potential for browse damage and also because habitat enhancement might be better served through reclamation with other species.

More detailed studies of conifer growth rates on seismic lines with different orientations, cut through stands of different ages, under variable site conditions and silvicultural treatments, are advisable prior to formulating long-term policy and management strategies regarding coniferous reforestation of seismic lines.

4.3 Wildlife Habitat Modification and Off-Highway Vehicle Access

Reclamation in areas such as Critical Wildlife Zones, where habitat enhancement is a desired land use objective, should take into account not only erosion control but also the potential of selected plant species for improving food and cover conditions and for restricting vehicular access.

Our observations along with a review of related literature suggest that moose, deer, elk, small mammals, and birds may all benefit from the increased diversity and cover of plant species on seismic lines compared to that of undisturbed natural forests. Deciduous shrubs and trees were extensively browsed within the study area. Their ubiquitous presence on seismic lines appears to provide a significant forage source, especially for ungulates. Further, shrub and tree growth sometimes limits line-of-sight down seismic lines; those wildlife species such as deer, which require hiding cover, may feed more extensively on lines where shrub and tree growth provide visual screening from roads, clearings etc.

Because of their relatively rapid growth under favourable conditions, deciduous trees and shrubs could also be of value for controlling OHV access, which can cause wildlife to leave or avoid foraging areas (Stelfox _et al_., 1976; Dorrance _et al_., 1975).

Control of OHV access might also be desirable for other reasons. We concluded from our observations that, although both damage to vegetation and accelerated erosion did not appear to be a widespread problem in our study area, it was a problem locally. OHV use may become more intensive in future with the probability of increased recreational activity along the Eastern Slopes. OHV use is recognized as a legitimate form of activity on lands within the Eastern Slopes, and several areas have been set aside specifically for recreational vehicle use. However, tighter controls on OHV use, and the establishment of more OHV use areas, will ultimately be necessary to reduce land-use conflicts with other resources and other users. Furthermore, OHV access control is a necessary corollary for successful seismic line reclamation; it seems pointless to revegetate seismic lines if vehicles subsequently travel over them.

Where access control and/or wildlife habitat enhancement are appropriate reclamation objectives, trembling aspen, balsam poplar, willows and Sitka alder are potentially useful species for reclamation.

1) The most suitable locations for planting are those where light and moisture levels are high. Line intersections are places where light levels are likely to be high enough to support good growth.

2) Vehicle access should be controlled until planted trees and shrubs have reached a sufficient height and density to perform this function. Therefore, some means of physical restriction, such as windrowing or spreading slash (roots and tree boles left after seismic lines are cut), across lines is advisable.

3) Plantings should be sufficiently dense to provide a definite physical and visual barrier to vehicle passage, and to provide wildlife with some measure of security. Plantings

should be carried out on a trial basis to determine the best stocking rate and species to plant under various conditions. However, as an initial guide, a 1.5m spacing of planted trees and shrubs over a linear distance of 30m along a seismic line is suggested to allow for some mortality and loss to animal browse and to provide the required density. Table 2 provides comparisons of stocking levels and costs of replanting 30m of seismic line at various spacings. Figure 8 shows one way of planting the intersection of two 8m wide seismic lines at two different planting densities.

4) Silvicultural techniques such as fertilization and scarification may enhance growth. It may be advisable to coordinate planting with the snowshoe hare cycle so as to avoid the peak, when severe browse damage could retard shrub and tree growth.

5. SUMMARY AND CONCLUSION

Vegetation studies in the Rocky Mountain House area of Alberta showed that some tree and shrub species frequently colonize seismic lines over a period of 10-30 years following line clearing. These species include lodgepole pine, black spruce, white spruce, trembling aspen, balsam poplar, Sitka alder and willows. The best growth of these species can be expected to occur where both light and moisture levels are high, such as at seismic line intersections. Coniferous reforestation of seismic lines is likely to be unsuccessful on lines cut through older stands where shading of the lines could reduce growth rates. Deciduous trees and shrubs could be useful for various reclamation purposes including wildlife habitat improvement, access control, and long-term erosion control.

Seismic exploration has affected a significant portion of Alberta's forested lands, and will probably continue to do so in the foreseeable future. The current trend in Alberta is toward integrated resource planning to optimize the delivery of various resources to Albertans. It therefore seems appropriate to reconsider the objectives of seismic line reclamation relative to provincial resource requirements. Our study has highlighted the potential value of trees and shrubs for attaining identified reclamation objectives such as wildlife habitat enhancement. Further studies of both natural and planted tree and shrub success on seismic lines in different forest ecosystems of the Province are therefore strongly suggested.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Canadian Petroleum Association and the Alberta Environment Research Trust for providing research funding. Sunburst Resources Ltd. made the presentation of this paper at the Conference possible, and also deserves our sincere thanks. Thanks also to those members of the Alberta Forest Service who provided assistance during the course of this study.

Table 2. Stocking levels and cost comparisons of replanting seismic lines with deciduous tree and shrub species

Planting spacing	Stocking stems/ha	Stocking stems/ac	Number[a] required	Cost[b]
4 per $0.25m^2$ (spaced 0.5m)	160 000	64 777	960	$2400
4 per $1m^2$ (spaced 1m)	40 000	16 194	240	$ 600
4 per $1.25m^2$ (spaced 1.5m)	17 777	7 197	100	$ 250
4 per $4m^2$ (spaced 2m)	10 000	4 048	60	$ 150
4 per $6.25m^2$	6 400	2 591	38	$ 95

---

a. Number of transplants required to replant a seismic line 8m wide over a length of 30m.

b. Assuming average cost per transplant of $2.50 planted. This figure is based on information obtained from the Reforestation and Reclamation Branch, Alberta Forest Service (P. King, pers. comm. December, 1982) as follows:

Cost of stock production: $1.00/plant on average (using Hillson Spencer-LeMaire containers and large-scale production (more than 100 000 transplants). Estimates obtained by the Alberta Forest Service from four contractors ranged from $0.94-$1.05 per transplant).

Planting cost: approximately $0.148/transplant on large-scale projects. Suncor Ltd. incurred a planting cost of $0.18 per transplant with a volume of 100 000 transplants.

Total cost (large volumes) = approximately $1.15-$1.20/transplant. However, as seismic line plantings are not likely to be carried out on the same scale, and as travel distances to planting locations on seismic lines may vary considerably, a more conservative figure of $2.50 per transplant is used here.

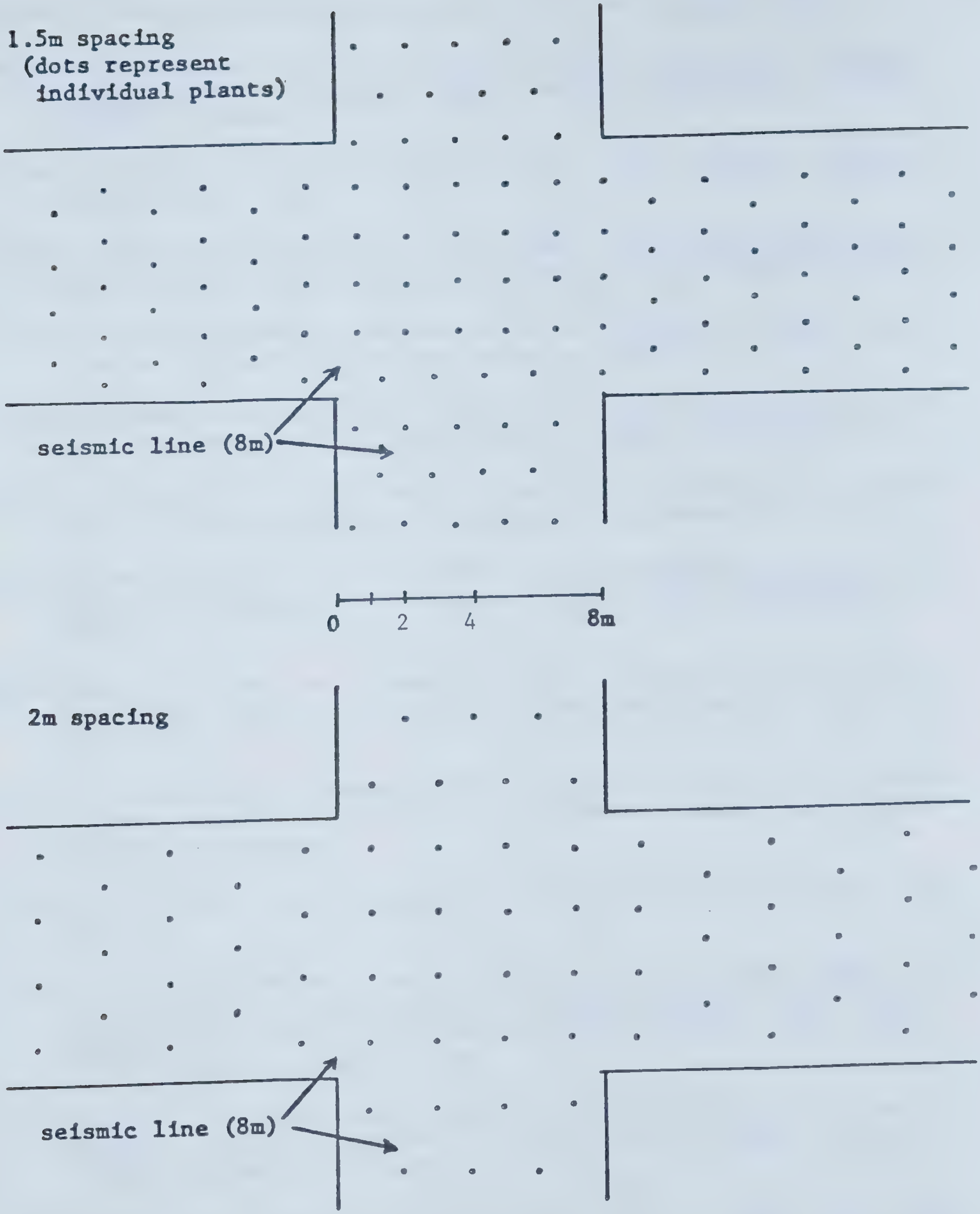

1.5m spacing
(dots represent
individual plants)
seismic line (8m)
0
2
4
8m
2m spacing
seismic line (8m)

Figure 8. Suggested planting pattern for deciduous seedlings at two different densities

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SESSION III-B

RECLAMATION

Ms. J. Urisk - Chairman

REVEGETATION OF OIL & GAS DISTURBANCES:
A METHOD FOR SELECTING
SEED MIXES, FERTILIZERS & APPLICATION METHODS

P.F. Ziemkiewicz
Reclamation Research Coordinator
Alberta Department of Energy and Natural Resources
9915-108th Street
EDMONTON, Alberta

ABSTRACT

Revegetation contractors in the Oil and Gas Industry frequently encounter a different set of circumstances at each job site. Work sites tend to be numerous and small and site conditions can be severe enough to result in revegetation failure. Much of the revegetation work is done by field staff and because of the nature of the work timeliness is critical and exhaustive consultation and study is often impractical.

The following paper was developed to provide a methodology for field staff to quickly assess significant site conditions and taylor their revegetation treatments to meet site specific requirements.

INTRODUCTION

Revegetation Objectives

Revegetation is the process of establishing vegetation on disturbed sites. It is a more limited process than reclamation in that it does not include materials handling, resloping and establishment of the desired end land use. For the purposes of this discussion we will assume that the materials have been handled and graded and that we are looking at a large patch of bare ground which is in need of plant cover.

In wildland revegetation the first objective is erosion control. Until the surface is stabilized attempts to impose higher value land uses (forestry, wildlife, recreation etc.) will fail. Reclamation surfaces are destabilized by three main factors: slope failures, water erosion and wind erosion. Slope failures are an engineering problem. The solution to water and wind erosion problems, however, are largely within the revegetation sphere.

While establishment of an erosion-controlling cover is of prime concern other factors should be considered. Revegetation in the oil and gas industry may face constraints due to fire hazard. Almost anything will burn if it gets hot enough. This certainly applies to vegetation, green or brown. The operator must judge whether the severity of the hazard warrants 100% elimination of on-site fire. If it does then do not plant vegetation. However, proper vegetation management can make the difference between a tolerable, infrequent smolder and yearly conflagrations.

Weed Control is another revegetation objective in the oil and gas industry. Linear disturbances make excellent avenues for noxious weed invasion. This may cause profound concern among ranchers, farmers and the Department of Agriculture. Over large areas the cheapest way to exclude noxious weeds is to establish competing vegetation. Most weeds are opportunists and do not compete effectively against established, perennial vegetation.

Recreation/Wildlife/Livestock uses are inevitable if not always entirely desirable side affects of revegetation. Recreation increases fire and erosion risks and grazing pressure usually ranges from too much to way too much. The reason is simple; most of the plants available for reclamation are forage crops which the Europeans have obligingly bred for centuries to enhance their appeal to cattle and sheep. Even wild grazers, faced with their usual stringy, thorny and semi-poisonous diets will gratefully locate and demolish reclamation plants. Legumes are particularly attractive to wildlife and livestock because of their high nutrient content. In fact, excessive grazing may eliminate the legumes from a reclaimed area.

METHODS

Revegetation Variables

In facing a revegetation problem one must meet the objectives with a rather limited inventory of treatments. These fall into three categories: 1) Species Selection, 2) Fertilizer Management and 3) Application Methods.

1) Species Selection

There are 15 grasses and 8 legumes which are used extensively in North America for revegetation. These forage and turf species are about the only species commercially available for reclamation in Alberta which are proven performers.

All of these species have their strong and weak points. On a given site if you have a feel for the climatic and soil factors and the management requirements it is fairly simple for an experienced individual to put together a successful seed mix. There is no substitute for experience when it comes to designing seed mixes. However, many situations arise where a seed mix must be specified in the absence of expert opinion. The following discussion is meant for such situations and will just about ensure a satisfactory seed mix for Alberta conditions.

Within our scope of discussion nine main factors will determine whether a species succeeds or fails. Along these parameters I have taken the liberty of ranking the 15 grass and 8 legume species on scales of 1-10 (Table 1) to indicate their relative suitability. Use of the Table is simple and involves the following steps:

Table 1. Species, Revegetation Parameters and Ratings

	REVEGETATION PARAMETERS								
	1 Drought Tolerance	2 Nutrient Deficiency Tolerance	3 Grazing Resistance	4 Fire Resistance	5 High Elevation Tolerance	6 Flooding Tolerance	7 Acid Tolerance	8 Salt Tolerance	9 Erosion Control
Grasses									
1. Canada Bluegrass	9	1	10	10	8	1	8	8	9
2. Crested Wheatgrass	10	1	10	9	2	1	1	9	8
3. Intermediate Wheatgrass	8	1	9	1	4	1	1	7	8
4. Meadow Foxtail	5	1	7	2	10	9	8	1	8
5. Orchardgrass	4	1	2	2	9	1	6	1	8
6. Perennial Ryegrass	5	1	6	5	2	1	5	1	8
7. Red Fescue	8	1	8	5	10	1	10	3	10
8. Red Top	1	1	5	5	10	8	9	1	8
9. Reed Canarygrass	3	1	7	1	-1	10	5	8	8
10. Sheep Fescue	8	1	5	8	10	1	6	1	5
11. Slender Wheatgrass	8	1	7	2	6	1	4	7	8
12. Smooth Brome	8	1	7	1	5	1	10	4	9
13. Tall Wheatgrass	8	1	10	1	2	7	1	10	8
14. Timothy	5	1	9	1	10	3	6	1	4
15. Western Wheatgrass	9	1	8	2	2	1	1	10	8
Legumes									
1. Alfalfa	8	10	4	5	5	1	1	8	8
2. Alsike Clover	5	10	6	8	10	1	7	1	8
3. Birdsfoot Trefoil	5	10	4	7	3	1	6	1	5
4. Cicer Milkvetch 1)	7	10	7	6	7	1	2	6	3
5. Red Clover	1	10	3	8	3	1	3	1	8
6. Sainfoin	8	10	4	5	3	1	1	7	5
7. Sweetclover 2)	9	10	10	1	1	1	1	10	1
8. White Clover	1	10	6	8	-8	2	3	1	8

1)= Use only Scarified Seed

2)= Though it rates high in some categories Sweetclover is not recommended due to its poor persistence.

1. Identify critical site parameters
2. Add up the rating values for each species
3. Divide by the number of parameters used
4. Select the three highest ranked grasses and two highest ranked legumes

Table 2 shows examples of this procedure for nine site descriptions. The results generally match my personal prejudices. (The Reader should take note that these ratings devolve from my accumulated opinions of plants and they should not be mistaken for unassailable truth). Where there is a tie score go with your own prejudices or whichever seed is cheapest. The critical part of this system is identification of the site parameters. These are simple enough that an accurate assessment of critical parameters will be quick and easy.

1. Drought Tolerance. If the soil is sandy or gravelly then you will probably have a droughty site. Also South facing slopes and most sites in Southeastern Alberta can be assumed to be dry. If in doubt include drought tolerance as a factor. The drought-hardy plants will do well in moist sites but non-drought-hardy plants will die on a dry site.

2. Nutrient Deficiency Tolerance. If you do not plan to replace topsoil or fertilize a site regularly then this factor should be included, mainly as a reminder to keep up the legume content of the mixes.

3. Grazing Resistance. Any wildland or pasture planting will get some wildlife or domestic grazing. If grazing pressure is likely to be heavy non-resistant species may be grazed out. Addition of this factor will keep grazing resistant species in the mix and provide a measure of erosion control even on heavily grazed spots.

4. Fire Resistance. Self-explanatory.

5. High-Elevation Tolerance. Many agronomic species will not persist at high elevations (above roughly 6,000 ft. in the South and 5,500 ft. in the North).

6. Flooding Tolerance. Include if ponding is likely to be a problem, even if sporadic.

7. Acid Tolerance. Strongly acid soils are rarely a problem in Alberta but they may crop up around sulfur stockpiles, acid drilling mud spills and in some of the black shales in the mountains (Fernie formation). Include only if strong acidity is going to be a problem (pH less than 5.0).

8. Salt Tolerance. Include if you expect salt spills or naturally saline soil.

9. Erosion Control. Some species develop erosion control more quickly than others. On erodible sites (slopes, sandy soils) this factor is very significant.

Table 2. Examples of Seed Mixes Predicted for Various Site Types

	Site Descriptions								
	A	B	C	D	E	F	G	H	I
	Foothills, Sandy Soil, Slope, Fire Hazard #1, 2, 3, 4 and 9	Foothills, Heavy Soil, Slope, Fire Hazard #2, 3, 4 and 9	Alpine, Heavy Soil, Slope, Poor Drainage #2, 3, 5, 6 and 9	Plains, Heavy Soil, Saline, Fire Hazard #1, 2, 3, 4 and 8	Peace Region, Heavy Soil, Saline #2, 3 and 8	Foothills, Acid Soil, Fire Hazard #2, 3, 4 and 7	Alpine, Acid Soil, #2, 3, 4, 5 and 7	Plains, Gravelly, Acid Soil, #1, 2, 3 and 7	Alpine, Gravelly Soil, Slope #1, 2, 3, 5 and 9
Grasses									
1. Canada Bluegrass	*78	*75	58	*76	63	*72	*74	*70	*74
2. Crested Wheatgrass	*76	*70	46	*78	*66	*52	46	55	62
3. Intermediate Wheatgrass	54	48	46	52	57	30	32	48	60
4. Meadow Foxtail	42	39	*62	28	21	39	52	46	*62
5. Orchardgrass	34	32	42	20	13	35	40	32	48
6. Perennial Ryegrass	50	50	36	36	-27	42	38	42	44
7. Red Fescue	*61	*55	57	47	33	*55	*65	*63	*74
8. Red Top	40	48	*64	26	23	50	*60	40	50
9. Reed Canarygrass	40	42	54	40	53	35	30	40	40
10. Sheep Fescue	52	47	44	46	23	50	60	50	58
11. Slender Wheatgrass	52	45	46	50	50	35	40	50	60
12. Smooth Brome	52	45	46	42	40	47	48	*65	60
13. Tall Wheatgrass	54	50	56	58	*70	32	30	50	58
14. Timothy	40	38	54	34	37	42	54	52	58
15. Western Wheatgrass	56	48	40	*60	*63	30	28	47	56
Legumes									
1. Alfalfa	*70	67	56	*70	*73	50	50	57	*70
2. Alsike Clover	*74	*80	*70	60	57	*77	*82	*70	*78
3. Birdsfoot Trefoil	52	65	46	54	50	*67	60	62	54
4. Cicer Milkvetch 1)	66	65	56	*72	*77	62	64	*62	68
5. Red Clover	60	72	50	46	47	60	54	40	50
6. Sainfoin	64	60	46	68	70	50	46	57	60
7. Sweetclover 2)	62	55	46	80	100	55	46	75	62
8. White Clover	66	*80	*68	52	57	67	*70	50	66

* = Recommended Seed Mix
1)= Use only Scarified Seed
2)= Though it rates high in some categories Sweetclover is not recommended due to its poor persistence.

2) Fertilizer Management

Topsoil is the best fertilizer. However if it is not available proper fertilizer management can be as significant as species selection in determining your final vegetation cover. Fertilizers are marketed according to their proportion of the three main nutrients: nitrogen, phosphorus and potassium expressed as % N-%P_2O_5-%K_2O. So urea is 45-0-0 and monoammonium phosphate is 11-46-0. Almost all revegetation sites need fertilizer. The secret lies in determining what kind (grade) and how much (rate). In revegetation it is safe to assume that nitrogen and phosphorus are in short supply. If you are the cautious type you will want to use an N,P mixed fertilizer. If you are prone to take chances you can cut fertilizer costs dramatically by using a straight nitrogen fertilizer (e.g., ammonium nitrate, urea, ammonium sulfate). Soil potassium is usually in adequate supply and can be deleted from further consideration.

The first fertilizer addition should provide 50-75 lbs/ac (Kg/ha) of nitrogen. If the plant cover starts yellowing and dying off by the middle of the first two growing seasons than a second or third application of 1/2 the original rate should be made the next Spring. Thereafter one should resist the temptation to fertilize unless erosion poses an immediate hazard. Excessive fertilization will only generate a fire hazard in thick, dry vegetation and create a feedlot for the local grazers. Also, overfertilization allows the grass to outcompete the legumes. It is much better to allow the legumes to develop and do what they do best: turn atmospheric nitrogen into useable nitrate and ammonium.

3) Application Methods.

The means of applying seed and fertilizer may also significantly affect revegetation success. In Alberta seeding and fertilizing should be done in Spring/early Summer if access is available. In the mountains early season access is usually limited. If late access would mean mid-Summer planting it is usually best to seed in Fall and fertilize in Spring. Do not apply fertilizer in the Fall. It will be gone by the time the seedlings need it.

Unless applied seed is covered by soil or mulch it will only serve as bird feed. Sometimes seeding on extremely rough or recently worked soil will produce an acceptable catch. However, to be sure either cultivate or harrow after seeding. Seed drills and Brillion-type seeders accomplish seeding and incorporation in one step but both require a smooth and nearly rock-free seed bed. They are also almost impossible to use on steep slopes. Their use, however, should not be ruled out on flat or subdued slopes and particularly on sandy sites or wherever topsoil has been applied. Proper use of a seeder or drill (which most farmers have) gives the best chance of success with the minimum amount of seed and machine time.

When using any of the broadcast methods (via aerial, tractor of hand-carried cyclone) 50 lbs/ac (Kg/ha) of seed is the standard recommendation. When a seed drill is used the seeding rate may be halved. These rates are high but are meant to cover a wide range of seed bed conditions. If you do not get good establishment with these rates then the problem lies elsewhere (poor seed bed/incorporation, soil toxicities, wrong seed mix or droughty conditions).

Seed and fertilizer should be applied together in the Spring and incorporated (harrowed) within a few days, the sooner the better. For isolated, small sites (less than 30 ac) perhaps the most effective method is to send in a five man crew with cyclone seeders just before the dozer leaves the site. A good crew can finish seeding and fertilizing a 30 ac site in about 4-5 hours and the dozer then drags a harrow around on its last pass.

For long linear disturbances, numerous small sites within a radius of less than 2 miles or very large sites (greater than 60 ac) aerial (Helicopter) application of seed and fertilizer is best. Site preparation is critical. Where there has been compaction due to vehicle traffic (roads, pipeline rights-of-way) ripping should preceed seeding and again harrowing should be the final step.

Hydroseeding is often the only way to apply seed, fertilizer and sometimes mulch to steep slopes and it is almost always the most expensive way. It is ideal for seeding active road cast banks, steep slopes or where erosion control is an immediate requirement. In such cases immediate erosion control may be achieved by using a hydro mulch, usually in conjunction with a soil binder. The mulch is usually applied at between 1000 to 3000 lbs/ac increasing with greater erosion hazard. Wood fiber mulches seem to give the best results. Also many chemical binders are on the market. These are applied at rates of 40 to 100 lbs/ac and help bind the mulch to the soil surface and improve soil structure.

Some binders are effective and some are a useless expense. Research in California (1) indicates that heavier rates of wood fiber mulch are as effective as some binders in reducing erosion hazard. However, at high rates of application fiber mulches may inhibit seedling germination and emergence. Work on logging roads on Vancouver Island (2) indicates that hydroseeding alone had as much effect in controlling erosion as hydroseeding plus hydromulching and binders. Hydromulching should only be used where immediate erosion is a concern and seedling establishment is expected to be slow. Keep in mind that soil is the best mulch and if possible stick with broadcasting and harrowing.

SUMMARY

1) SEED MIXES

There are about 15 grasses and legumes to choose from. The number of possible combinations is staggering. Fortunately, for the sake of simplicity many of these species are mediocre performers. If you had a choice of only five species to use across all oil and gas disturbances in Alberta you would do reasonably well using Red Fescue, Crested Wheatgrass, Canada Bluegrass, Alfalfa and Alsike Clover.

2) FERTILIZER MANAGEMENT

The best way to eliminate this as a concern is to respread topsoil. Otherwise in the initial year use about 50-75 lbs/ac of nitrogen and as much phosphorus. If further fertiliztion is needed in succeeding years use half as much. Avoid more than two years of maintenance fertilization.

3) APPLICATION METHODS

Several methods are available. Use one which incorporates the seed into the soil (Broadcast and Harrow, Seed Drilling, Brillion Seeder). If steep slopes make this impossible hydroseeding should be considered.

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2) Carr, W.W. 1977 Hydroseeding of Forest Road Slopes for Erosion Control & Resource Protection. M.Sc. Thesis Univ. of B.C. Faculty of Forestry. 55p.

APPENDIX

NUMERICAL EXAMPLE: Use of the Seed Mix Selection Method see Table I and Site Description 'A' Table 2

Species		Drought	Nutrient	Grazing	Fire	Erosion Control			
Canada Bluegrass	Parameter	1	2	3	4	9		TOTAL	
	Score	9 +	1 +	10 +	10 +	9	=	39	=.78=78%
	Possible	10 +	10 +	10 +	10 +	10	=	50	
Redtop	Parameter	1	2	3	4	9			
	Score	1 +	1 +	5 +	5 +	8	=	20	=.40=40%
	Possible	10 +	10 +	10 +	10 +	10		50	

Formula for Calculating Scores

$$\text{Species Score} = \frac{\sum_{i=1}^{n}}{10n} \text{X}100$$

Where: n = Number of Parameters

R = Rating

s = Species

$\sum$ = Summation

RESTORATION FOLLOWING TRANSMISSION LINE CONSTRUCTION

By Mr. V.D. Horsley, Transmission Environment Department, Ontario Hydro.

ABSTRACT

Restoration procedures on Ontario Hydro rights-of-way are designed to minimize the impact of construction of the transmission facilities and to ensure an environmentally acceptable right-of-way that can readily be maintained. It is considered an integral part of the transmission line development and right-of-way maintenance.

The paper reviews Ontario Hydro's restoration practices. Problems requiring nonstandard or special recommendations indicative to construction, maintenance, and/or secondary land use are emphasized.

A number of case studies are cited to provide an overview of restoration on transmission line rights-of-way.

INTRODUCTION

It is Ontario Hydro's policy that in providing for safe and reliable electric service at a low cost over the long term that it develop and implement sound environmental practices. To this end, transmission facilities are planned and developed so as to minimize adverse environmental effects caused by construction, operation, and maintenance.

Restoration is an integral part of the construction of transmission lines as well as the maintenance of the right-of-way. It is designed to meet a number of objectives: to minimize the impact of the construction of the transmission lines; to ensure a right-of-way that is environmentally acceptable; and to leave a right-of-way that can be readily maintained. We meet these objectives on rights-of-way for high voltage transmission lines through planning, mitigation, and restoration including natural restoration systems, and, where required, the use of more expensive mechanical means where they are cost-effective.

PLANNING TO MINIMIZE ENVIRONMENTAL IMPACTS

A preferred route is selected through an Environmental Assessment (EA) in which alternative routes are evaluated involving an extensive public involvement program. The EA is submitted to the Ministry of the Environment (MOE) for review and approval; and is subject to an Environmental Assessment Hearing. The route selection process attempts to avoid and minimize most of the significant environmental areas identified in the planning process.

Planning for the construction of the line including location of access routes and towers, and construction activities is designed to minimize environmental impacts while meeting costs and schedules.

The Transmission Environment Department has the responsibility to ensure that all the environmental concerns are looked after in the development of the right-of-way, that the right-of-way has sufficient clearance for safe operation of the lines, and the right-of-way is restored so as to minimize maintenance requirements.

To this end, we carry out detailed constraint mapping along the centre line, identifying constraint areas and environmentally sensitive areas.

Constraint areas identify environmental concerns where standard construction and restoration practices are sufficient to mitigate the concern. The Construction and Site Restoration Guidelines (1981) outline those procedures which are routinely carried out as standard practice by field personnel. The report lists construction activities, possible effects, and the recommended mitigation. The guidelines are used by construction and maintenance personnel to minimize environmental impacts; to assist in those reviewing environmental assessments, to inform the general public of Ontario Hydro's activities.

Environmentally Sensitive Areas are identified where the significance and/or sensitivity of the area is such that specific and/or nonstandard mitigation is required to minimize the impact.

Locating the access routes to avoid concerns is the first means of minimizing impacts and restoration costs. Based on tower layout and constraint mapping access routes are identified in consultation with the property owners. Property owners have a unique role to play in providing site specific information such as in the location of tile drainage.

A Preconstruction Route Plan is then prepared outlining tower locations, access routes, stream crossings, selective cutting recommendations, and Environmentally Sensitive Areas with special mitigation and restoration procedures. The plan is reviewed by interested ministries and agencies and is filed with the MOE. It is also used as a working document by our field crews during construction.

Construction then proceeds with selective cutting of the right-of-way, access construction, tower erection, stringing, and restoration.

STANDARD RESTORATION

Restoration is not considered simply a cleanup exercise but is "likened" to ongoing mitigation throughout construction beginning with the selective cutting of the right-of-way. In 1970 Ontario Hydro instituted a policy of selective cutting and maintenance of their right-of-way. In the clearing of the right-of-way, only incompatible trees that, when mature, will interfere with the safe operation of the lines are removed. The maximum allowable height of the tree (as per Table 1) is determined by the voltage and is depended upon the topography.

Table 1

Minimum Tree Clearance From Established Maximum Sag Position of Conductor

Voltage	Minimum Standing Clearance*	Minimum Falling Clearance*	
500 kV	6.0 m	3.0 m	
345 kV	6.0 m	3.0 m	
		Sound Trees	Unsound Trees
230 kV	4.5 m	0 m**	2.0 m
115 kV	3.0 m	0 m**	2.0 m

*These are minimum permissible clearances. During line clearing operations, an allowance must be made for the growth that will occur during the clearing cycle.

**In general, sound trees adjacent to these lines shall not be treated even though they are tall enough to have less than the minimum permissible falling clearance. However, in inaccessible locations, trees may be treated. This judgement shall be based on pertinent economic and environmental factors.

A cover crop is seeded shortly after the right-of-way clearing. It serves to protect soils from erosion, competes against undesirable weed species and incompatible shrubs and tree species, and generally provides for an aesthetic right-of-way.

In northern Ontario, where there are large tracts of forest land, rights-of-way are aerial seeded. On rights-of-way through smaller woodlots in southern Ontario, the seed is applied by a sleigh-mounted cyclone seeder on the snow behind a snowmobile or by a hand cyclone seeder in very small sites.

In Northern Ontario, we seed a mix of Juno Orchard Grass, Perennial Rye, Creeping Red Fescue, Tall Fescue, Reed Cannary Grass, and Champ Timothy at 22 kg/ha. In agricultural areas a pasture mix of Champ Timothy, Ladino White Clover, Perennial Rye Grass and Red Top is seeded (22 kg/ha). However seed mixtures are tailored more to site conditions, or in the case of agricultural lands legumes are selected to be compatible with adjacent forage crops.

During tower construction on arable land, spoil material from augering foundations is normally trucked away. After construction there is a general cleanup around the tower sites with grading and levelling.

Access requirements of heavy machines are responsible for many of the impacts to agricultural lands, stream crossings, wetlands and other sensitive areas. Impacts are mitigated through the location of the access, scheduling of access and construction, type of access (ie, gravelled access, corduroy) and stream crossing specifications for fords and culverts. Upon the completion of construction, access is restored as nearly as possible to original condition. This involves removing temporary culverts where permanent access is not required, reinstating fences, removing gates, and removal of gravel. Where corduroy roads or gravelled access are used in wetlands they are normally left as permanent access.

Rutted and compacted soils are restored along access routes and at tower setup areas, erection areas and stringing setup areas. Ruts are backbladed and compacted soils are chisel plowed and rototilled. Depending upon the severity of compaction, rototilling will prepare an excellent seedbed. However, under severely compacted soils (in terms of soil depth and increased soil strength) chisel plowing is required to break up the soil and re-establish good drainage. We are following the chisel plowing with a once over with the rototiller to provide a good seedbed. Access roads and disturbed areas are then seeded with an appropriate forage in consultation with property owners.

On farm land where the cutting of wood lots is a natural extension of a farm field the grubbing of the area may be recommended where stumps and roots are removed and cleaned up for agricultural use.

Tile drains are protected during construction with reinforcing of steel plates, timber mats or gravelled access. However, if any tiles are damaged during construction Ontario Hydro replaces or repairs the drains.

Where erosion has occurred or is likely to occur on disturbed soils, steps are taken to stabilize soils.

Tree and shrub plantings may be done where screening is required to reduce visual impacts such as along roadways or to adjacent property owners.

NONSTANDARD RESTORATION

Nonstandard restoration steps are often required and Specialized vegetative and mechanical techniques are recommended where they are most cost-effective.

Windscreens were used to prevent wind erosion of a sandy soil in Northumberland County. In this situation, lines of trees were left during the cutting to prevent a wind tunnel effect. The areas between were seeded by hand. However, because of poor soil conditions, it was necessary to drill the seed and fertilize to obtain good seed establishment. The windscreens were removed once the cover was well established.*

Gully erosion occurred at another site in Northumberland County after the right-of-way was cut on a sandy loam slope with internal seepage. Clearing of the right-of-way allowed greater precipitation to penetrate the soil surface. In addition, the problem was aggravated when the logs were piled at the bottom of the slope adding a considerable weight and interrupting the natural drainage. To restore the gully the banks were graded and lined with filter fabric and covered with stone. A dyke was built at the downstream end with sand bags and gravel bags. Gravel bags were inserted to permit the free movement of water.

Tower sites are not always located ideally and can present specific problems. During the construction of a line within a narrow right-of-way in London, two legs of a steel structure were located in a 3.5 m deep storm channel with the other two legs located on top of the channel wall. It was necessary to secure the footing and protect the sidewall channel while maintaining the flow regime for a 100-year storm event.

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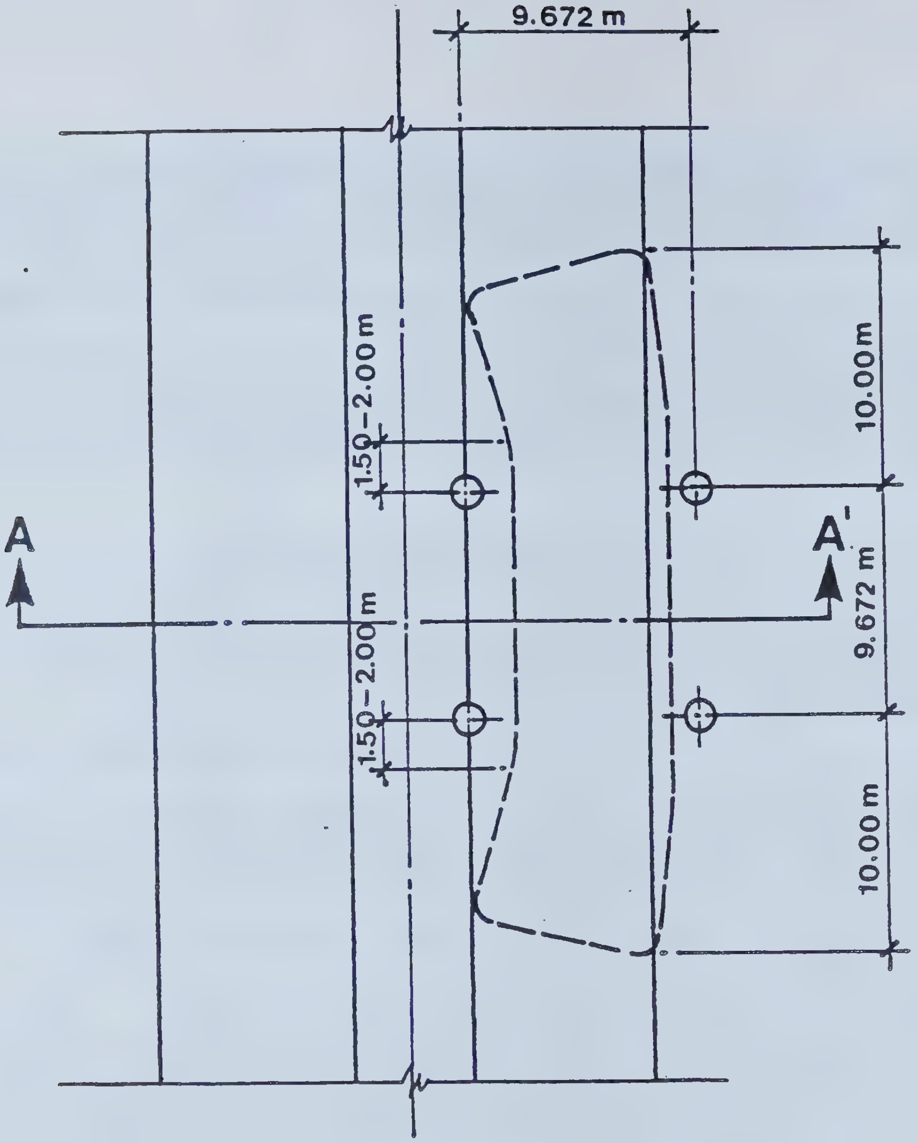
*Welch, W.E., Paper presented to the Crops in Reclamation Course, Crops Department, University of Guelph, 1983.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10.00 m
1.50–2.00 m
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9.672 m
1.50–2.00 m
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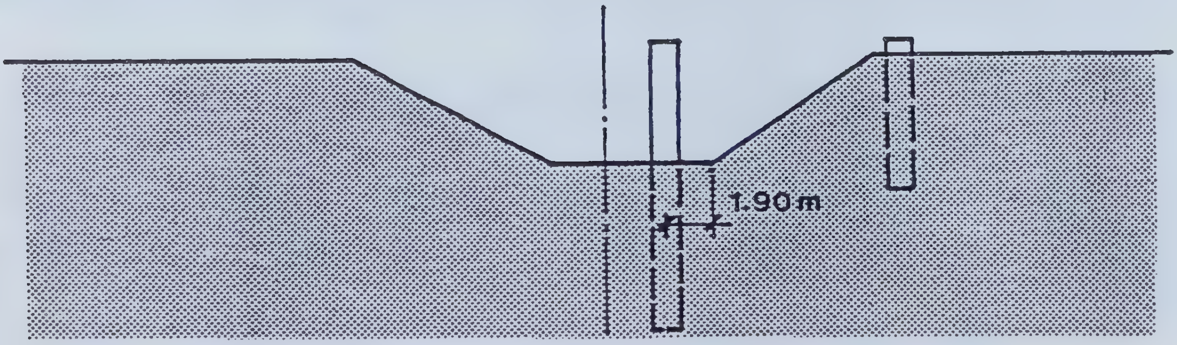
PLAN



SECTION A-A'

FIGURE - 1
STORM CHANNEL PROTECTION

To accomplish this the channel wall was cut back approximately 1.8 m (6 ft) to accommodate the volume of water displaced by the footings (1.5 m [5 ft] in diameter) and the width of the bank protection. (See Figure 1) The excavation was started about 10 m upstream and 10 m downstream of the tower to minimize scouring at high water levels. The maximum depth was reached at the tower site and extended 2 m to each side of the tower. The channel wall was then stabilized with installation of interlocking bricks.

In some sites several concerns may demand attention during restoration.

The laying of a submarine cable across Long Reach in Prince Edward County also involved laying a subterranean cable extending back from each shoreline. On the east shore this meant clearing a deciduous forest area back a distance of 300 m on a steep slope (1.5:1 to 2:1) of very sandy soils. Long Reach is a major boating access to Lake Ontario and has a high recreational use. Major concerns included stabilizing the slope, minimizing the visual impact by attempting to blend the right-of-way into the existing landscape, and discouraging secondary land use of the now cleared shoreline.

Final restoration could not begin until mid-September and because of concerns about leaving the slope exposed through the winter and vulnerable to spring thaw it was decided that pegging sod on the steepest portions was the best assurance for slope stability.

Shrubs were planted the next spring to enhance slope stabilization as well as to enhance the visual aesthetics and deter access. The more level upper and lower slopes were hand seeded and covered with an erosion control blanket.

Restoration is not restricted only to the construction of new transmission lines. Problems arise during regular operation and maintenance. For example, a security problem existed at a Distribution station in Northern Ontario where surface runoff from the DS was eroding a wood pole structure located on a steep ravine slope. The problem was further complicated with sidewall seepage. Restoration which entailed intercepting seepage with tile drainage, fill and grading to redivert the surface runoff, seeding exposed soils to grass and covering with an erosion control blanket, and finally the planting of shrubs to further enhance soil stability.

Secondary land use can also present problems. Pipelines use our rights-of-way and from time to time it may be necessary for the pipeline company and ourselves to cooperate in restoring disturbed areas. For example, a pipeline crossing of a creek near Oakville, Ontario exposed a shale bedrock which was susceptible to rapid weathering and erosion, especially as it was being undercut with bank erosion by a stream at the base of the slope. The overburden was steeply sloping and highly susceptible to erosion and slumping.

To restore the slope the toe of the slope was first stabilized using gabion baskets. The slope was regraded, seeded, and covered with an erosion control blanket. Riprap was used to protect areas where the water was concentrated. The slope is now stable and has needed little maintenance.

CONCLUSION

Ontario Hydro's activities in the planning and development of transmission lines are carefully scrutinized by an environmentally concerned public. In order to minimize the environmental effects, our field crews now carry out many standard restoration and mitigation techniques which were treated as special procedures during the building of the high voltage transmission lines in the mid-1970's. We will continue to develop and improve on our restoration techniques in order to develop transmission corridors within environmentally acceptable standards.

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Ontario Hydro, Construction and Site Restoration Guidelines for Transmission Facilities, 1981.

REHABILITATION OF AGRICULTURAL LANDS

DAWN-KERWOOD LOOP PIPELINE

I. Moncrieff, E.E. Mackintosh, L. deVries and M. Hoffman

Union Gas Ltd; Ecological Services for Planning Ltd; Robinson, Merritt and deVries Ltd. and Smith, Hoffman Associates Ltd.

ABSTRACT

Significant crop yield reductions have been noted along the NPS 42 pipeline, Dawn-Kerwood section, several years after construction. A three year study was implemented in 1981 to identify significant causes of crop yield losses, establish test plots on farm fields, test the effectiveness of the proposed remedial program, and monitor crop yield responses.

An assessment of the program to date is provided, together with proposed recommendations for rehabilitation of agricultural lands following pipeline construction.

BACKGROUND

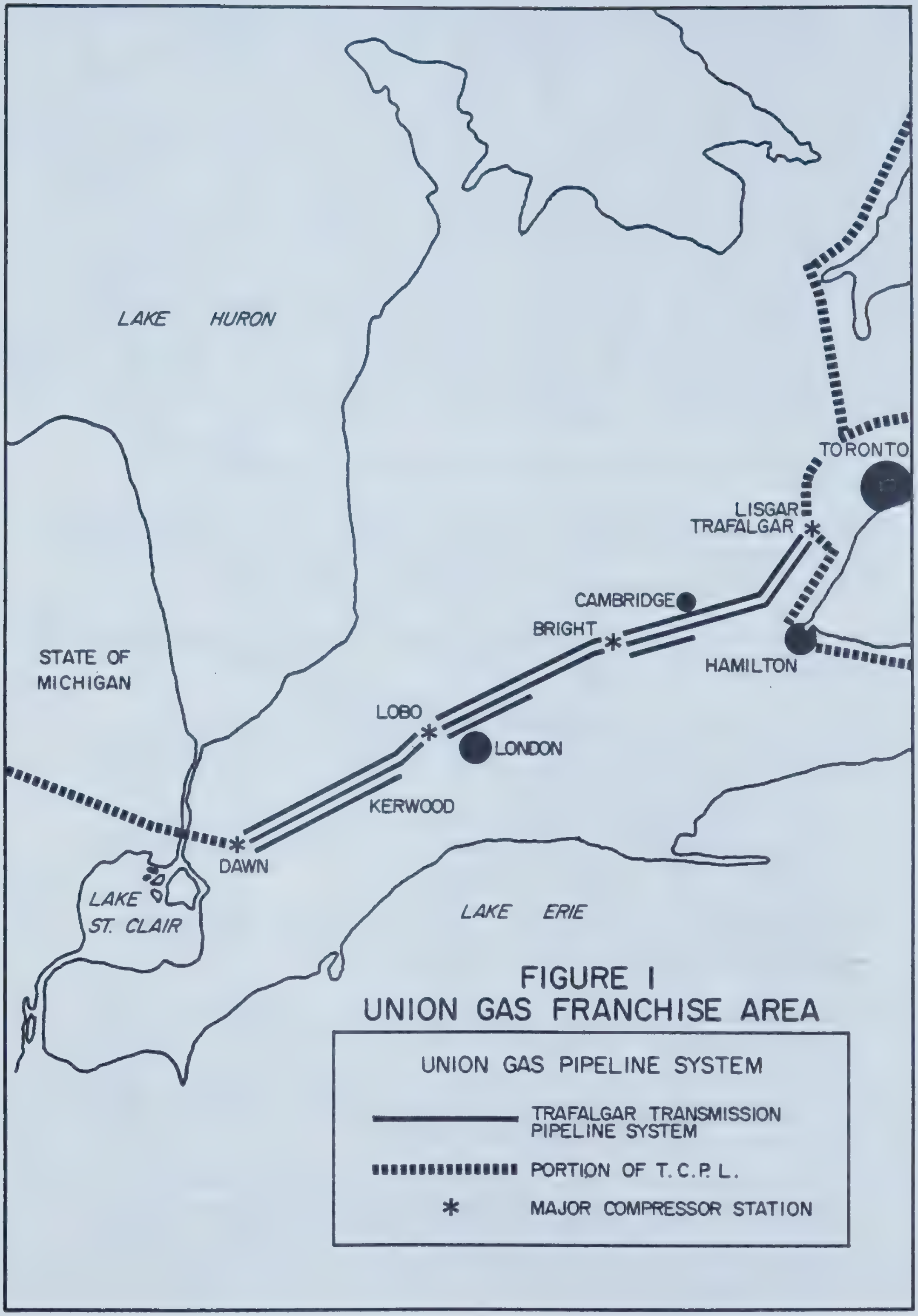
Union Gas is one of Canada's largest natural gas companies and provides a full range of services to its 500,000 customers including production storage, distribution and transmission. Currently, the company operates five major compressor stations within the franchise area (Figure 1) for the purpose of moving gas and maintaining pressure in the pipeline system. The Port Alma Station is located on the shores of Lake Erie south of Chatham while the remaining four stations are located on the main Trafalgar Pipeline Transmission System which runs from Dawn Township in southern Lambton County to the Lisgar Meter Station in Mississauga and interconnects with the TransCanada Pipelines System (T.C.P.L.).

The Trafalgar system consists of three pipelines: a 26" diameter line constructed in 1957; a second loop of 34" diameter pipe constructed from 1964 through to 1970; and a 42" diameter pipe on which construction started in 1974.

As a result of conditions imposed by the Ontario Energy Board, the 42" construction program is taking place over an extended period of time in short 16 to 20 kilometre sections as the need requires. The first of these 42" sections, the Dawn-Brooke valve, was identified and received approval from the Board in 1974 and construction began on November 1, 1974.

The 1974 general construction specifications required a 75' wide easement, and some environmental restoration procedures including topsoil stripping over the trench. However, with the two existing pipelines installed under less rigorous specifications and conditions, a third larger pipeline did little to improve the potential impact on the agricultural environment. The problems were further aggravated by the late start update and onslaught of winter.

After approximately 8 kilometres of trenching and welding (Dawn to Enniskillen Valve), the project was postponed due to technical problems encountered with the pipe and field welding. Reconstruction of the initial section from Dawn to Enniskillen and the continuance to the Brooke Valve began in September, 1975. Any topsoil that had been removed from trench area in 1974 was subsequently lost when a combination of deterioration weather conditions and the replacement of the pipe turned the right-of-way into homogeneous, saturated topsoil/subsoil mixture. Due to the constant movement of equipment along the travelled portion of the right-of-way mixing of the topsoil and subsoil occurred up to a depth of 24".



LAKE HURON
STATE OF MICHIGAN
TORONTO
LISGAR
TRAFALGAR
CAMBRIDGE
BRIGHT
HAMILTON
LOBO
LONDON
KERWOOD
DAWN
LAKE ST. CLAIR
LAKE ERIE
UNION GAS PIPELINE SYSTEM
TRAFALGAR TRANSMISSION PIPELINE SYSTEM
PORTION OF T.C.P.L.
MAJOR COMPRESSOR STATION

FIGURE I
UNION GAS FRANCHISE AREA

Under normal conditions the crop damage compensation program would have provided the property owner with sufficient compensation over a five year period when he would have theoretically approached full productivity. It soon became apparent that the damage caused by the construction was far greater than anticipated and at the end of the agreed five year period relative crop yield reductions over the easement were measured to be in excess of 40% and 50% from that of the adjacent field (Figure 2). At this point, Union Gas decided to investigate the problem in detail and established a three year research program directed toward testing a restoration procedure which would reduce the long term crop damage along the pipeline system from Dawn to the Brooke Valve. An additional section of 4.5 km from the Brooke Valve to the Kerwood Valve constructed in 1976 under improved conditions was added since soil conditions were similar.

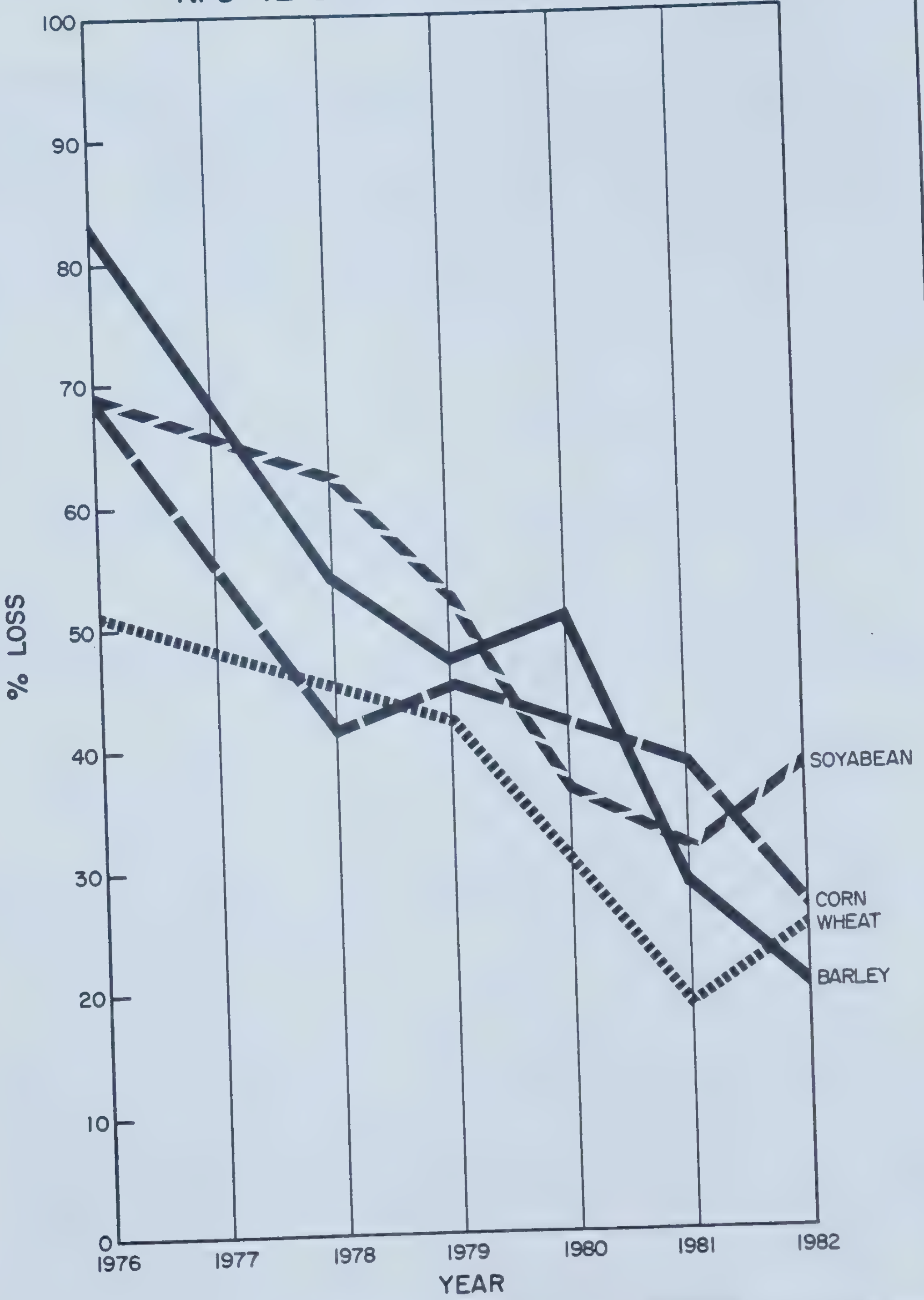
The specific objective of the study was to:

> "develop and implement land rehabilitation measures which would reduce the impact of past construction activities on agricultural crop yields".

To accomplish this, the following set of sub-objectives were outlined as follows:

1) To document significant problems along the pipeline which affect agricultural productivity and rehabilitation of the right-of-way.
2) To collect and evaluate data on soil conditions, crops and management practices associated with the problem areas.
3) To research, develop and implement remedial programs on selected problem areas after an evaluation of data collected.
4) To recommend a rehabilitation program for implementation along the Dawn to Kerwood easement.
5) To test the effectiveness of the remedial programs by measurement of agricultural crop yields on and off the right-of-way.
6) To review current construction practices and technical specifications used by Union Gas in pipeline rehabilitation and to modify and upgrade these as a result of the findings of this investigation.

FIGURE 2 - PERCENT LOSS IN CROP YIELDS FOR NPS 42 DAWN - KERWOOD PIPELINE LOOP



MATERIALS AND METHODS

Site Selection

A preliminary review of approximately 126 farm properties was completed along the 41 km right-of-way in 1981. The general characteristics of each site were recorded and included notes on soils, crops and drainage and comments on problem areas and possible causes. The data from this assessment were used to select 20 farms so that a cross section of problems could be examined inlcuding those dealing with specific soil properties and crop types, and those related to the effects of various farm management practices.

Each farmer was interviewed to obtain detailed information on the following:

a) background information on the physical nature of the farm;
b) farm management;
c) the farmer's perception of the problems associated with pipeline construction; and
d) the way in which the farmer treated the land affected by pipeline construction.

A soil and crop monitoring program was undertaken during the fall of 1981 and also, in 1982 and 1983.

Soil Analyses

Soils along most of the Dawn-Kerwood section consist of lacustro-till, clay to heavy clay soils. Topography is relatively flat and the soils are poorly drained.
The soils on each farm site were inventoried. Pits were also dug on four separate farms using a backhoe. These pits measured approximately 1 m in width and up to 1 m depth. The depth of pits varied so that tile beds were not disturbed and the trench was extended from the 26" pipeline through to the 42" pipeline. A separate pit was dug for control sampling at a distance of about 15 m from the 42" pipeline. General characteristics of soil texture, soil structure, friability, plasticity and soil colour, as well as, soil draiange and stoniness were recorded. Samples were collected for analysis at the control site and above a 34" and 42" pipeline and between these two pipelines. Samples were taken at two depths; 0-20 cm and 20-40 cm.

The samples were analyzed for general soil fertility levels at the Soil Test Lab, University of Guelph. Analysis were also done on bulk density, available soil water storage and particle size distribution.

Cross-section profiles were taken on 5 farms using a rod and engineering transit. These were usually taken at 2 to 4 sites per farm and extended from a control site across the entire width of the right-of-way to give some indication of micro-topographic variations and hence, surface soil drainage.

Crop Monitoring

The crop monitoring program consisted of 3 phases: a spring examination to determine seedling emergence; a summer examination to determine general health and vigor; and a fall phase which included sampling of crops for yield determinations. Details on plant height, density, form and colour were recorded. The sample plots were randomly located and replicated three times on the pipeline area or trench of the 42" pipeline, the travelled portion of the right-of-way to the south of the 42" pipeline, and the adjacent control or farmer field. In the case of soyabeans and white beans, individual plants were counted and the condition of the plants in the sample noted. For the cereals, a count was made of the number of stems in the sample plot. The height, form and colour were noted and any evidence of stress or nutrient deficiencies recorded. Plant and stem counts from the 3 replicas were added together and averaged.

The crop data were used to evaluate mortality in the emerging soyabean crop and to assess the problems with respect to differences in stem population and plant vigour in the cereal crops between the pipeline, right-of-way and field. The data provided the base on which to assess the early growth response as well as providing a bench mark from which to assess the change as the crop matured.

Crop yields were determined just prior to the farmer going on the field to harvest his crop. A 3 m sample of the crop was cut, bagged, allowed to air dry and stored for subsequent analyses.

Subsoiling Program

Results from the field monitoring program in 1982 indicated that amelioration of the adverse soil properties could probably be overcome by implementation of a subsoiling program and also by the introduction of a post-rehabilitation cropping program which included a legume-forage mixture. As a result of these observations, each farmer was contacted to determine their interest in participation in a subsoiling program and seeding of a legume, such as alfalfa. Of the 20 original farmers, 14 agreed to participate in the 1982/83 program. On each of these farms, alfalfa was seeded in May of 1982 along part of the right-of-way. In late July and early August plots on each of the farms were subsoiled to a depth of approximately 50 cm (20 inches). For the purpose of establishing subsoiling experiments, the right-of-way within a farmers field was divided in half and subsoiling was undertaken on one half of the site while the remaining half was left in its original state. This provided for a direct comparison between subsoiled and non-sub-soiled areas along the right-of-way and as well, a comparison with the adjacent farmer field or control area.

The crop assessment also included an evaluation of the alfalfa catch on those plots which were overseeded in May of 1982. The number of plants were counted in a 930 sq. cm. plot and these observations were repeated for both the 1982 and 1983 crop season.

In addition to the plots layed out on the individual farm properties, an experimental plot was designed and set out on the Union Gas property adjacent to the Dawn Compressor Station. The purpose of this plot was to allow a longer term evaluation of the affects of subsoiling and also the anticipated benefits of adding a legume/forage mixture to the post-reclamation cropping program. The establishment of these plots will allow Union Gas to carry on the monitoring program for additional 1 to 2 years. Treatment of the plots at the Dawn Compressor Station site are the same as the remainder of the individual farm plots, that is, the adjacent farmer fields. The plots included treatments on establishment of alfalfa and sweet clover (white blossom) in combination with subsoiling.

OBSERVATIONS AND EVALUATION

Soil Conditions

Field examination of the farms during the fall of 1981 and 1982 revealed that the reduction in crop losses were due to two major problems. Firstly, it was obvious that the soil physical properties had adversely affected yield as a result of pipeline construction. The original coarse, angular to subangular blocky structure characteristic of the B horizon from control sites had been destroyed and altered to massive structure (Figures 3 & 4). Numerous stress features such as pseudo-platy structure and slickensides were evident in the subsoil overlying the trench. Microhydromorphic conditions had also developed since construction. The interior of the massive soil clods contained colours on the 5-7Y and gley munsell color charts as opposed to the original prominant ochric mottling found under undisturbed field conditions.

In spite of the high bulk density (1.55-1.80 g/cc) recorded on the adjacent control areas, root penetration was evident along cracks, voids and interpedal faces to a depth of 1 m. The absence of these vertical structural features in soils over the pipeline has restricted root development to the plow layer or approximately the top

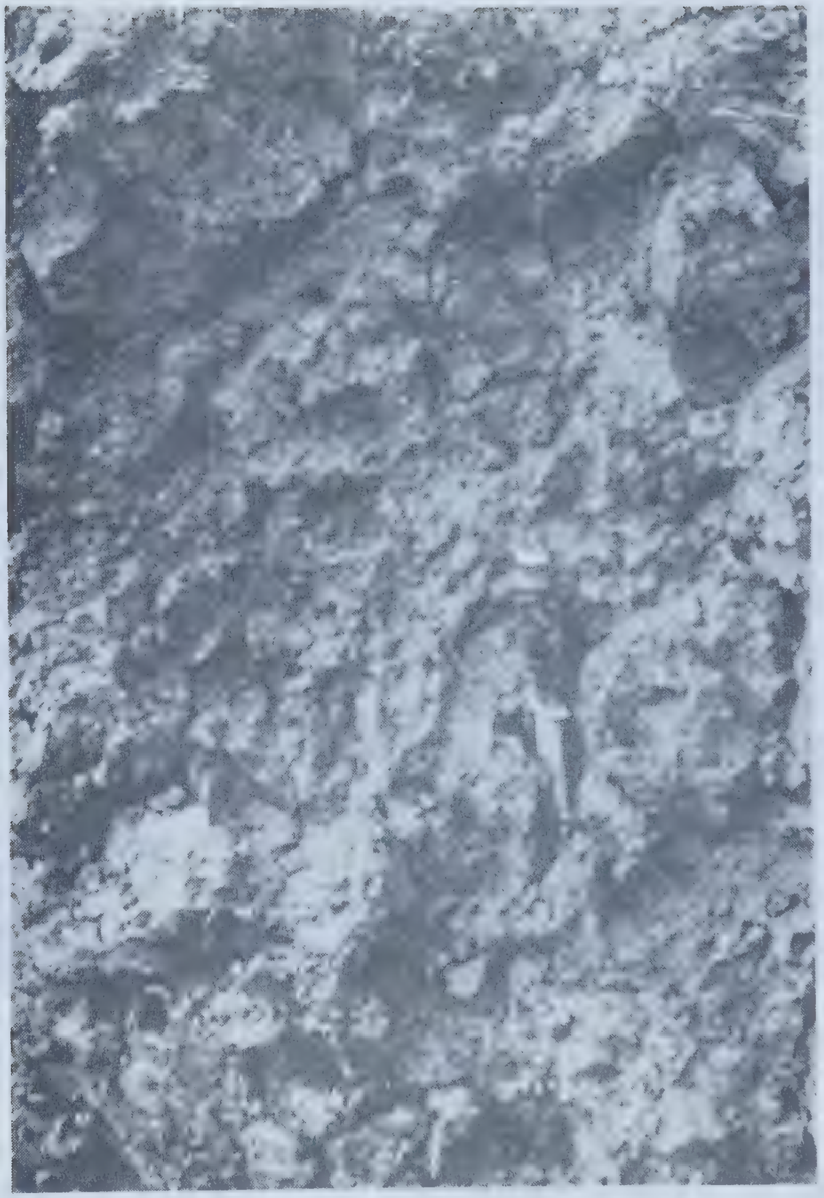


FIGURE 3: UNDISTURBED SOILS NORMALLY HAVE COARSE ANGULAR TO SUBANGULAR BLOCKY STRUCTURE WHICH ALLOWS VERTICAL ROOT PENETRATION TO 1 M OR MORE.

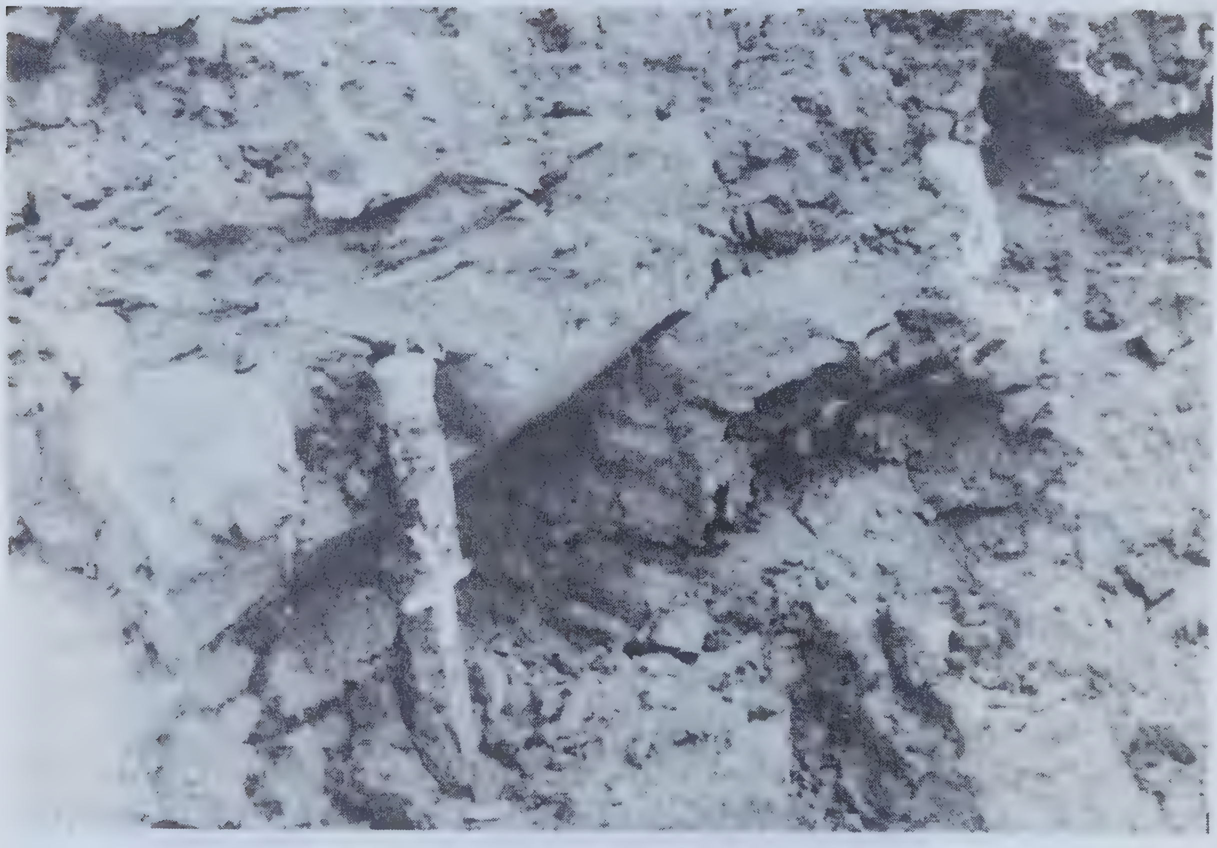


FIGURE 4: SOILS IN THE PIPELINE TRENCH HAVE DEVELOPED MASSIVE STRUCTURE WHICH RESTRICTS ROOT PENETRATION TO THE PLOW LAYER.

15 cm even though bulk density levels are similar to the control area.

The lack of macropores and vertical structural features in the modified soil over the trench significantly reduce air and water movement, as well as root penetration. The volumetric water content of undisturbed samples taken from over the trench are 43.2 and 38.7 per cent for 1/3 and 15 bars, respectively. The 4.5 per cent available soil water storage compares to 9.7 per cent on the adjacent undisturbed lands.

In addition to adverse soil structure, it was also observed that micro-topographic features occur along the right-of-way which results in local ponding of water after intense rainfall events. These latter features could be overcome through proper surface drainage,however, where this drainage is not provided ponding of water can result in reductions in crop yields and general damage to the overall health and vigour of the crop.

It was interesting to note from the cross-sections dug perpendicular to the pipeline that even over the 26" pipeline which was installed 26 years ago there was little evidence to indicate that reformation of natural structure was underway. In the absence of physically breaking-up the compacted soil layers or the establishment of crops that can root deeply, and thus, gradually break up the compacted layers, reformation of natural soil structure is an extremely slow process.

These observations on the general soil characteristics indicated that successful amelioration of these sites would have to involve a procedure which physically broke-up the subsoil and/or provided some surface drainage. This was the basis for establishing a subsoiling program in 1982.

Subsoiling Program

A winged or duck-foot design agricultural subsoiler was used for subsoiling properties along the right-of-way. The subsoiler consists of two types of shanks:

- a front row of 4-chisel teeth of approximately 66 cm length spaced at 80 cm intervals; and

- two winged or duck-foot shanks (Figure 5) 90 cm in length and set approximately 1.22 m apart at the rear of the machine.

The subsoiler was attached by a 3 point hitch and pulled by a 175 horse-power 8 wheeled 4-wheel drive John Deere model 8440 tractor. Field experience showed that traction rather than horse-power was the major limitation to

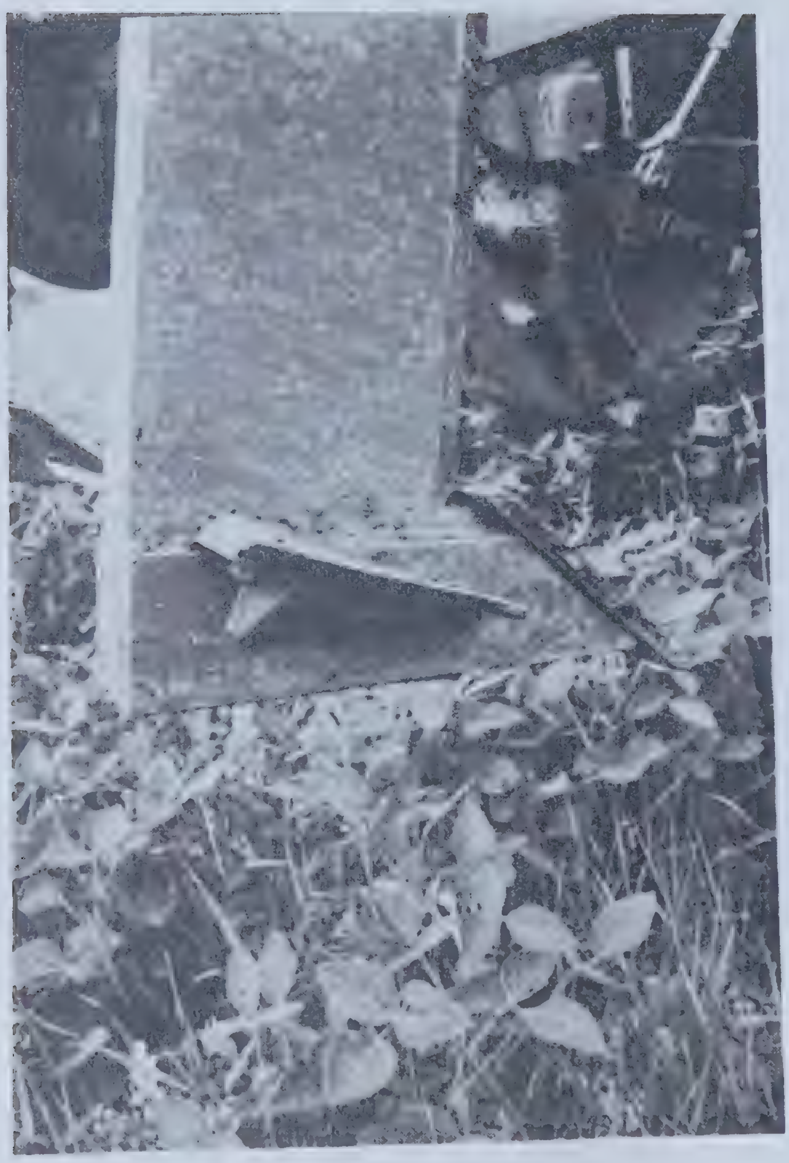


FIGURE 5: SUBSOILER DUCK-FOOT BLADE

The wings on the side of the blade lift the soil and create a shattering action.

subsoiling operations; thus, the preference for an 8 wheeled, 4-wheel drive tractor.

The working depth of the subsoiler varied from 40 - 60 cm depending on moisture content of the soil. Soil materials were shattered to this depth and large clods of dense, compacted soil were evident at the soil surface (Figure 6). Subsequent field inspection showed that up on exposure of the dense clods to normal wetting and drying cycles they became quite friable and worked up into a good seed bed.

Within the profile, shattering of the soil had occurred from the bottom of the winged shank through to the soil surface. Shattering occurs for a distance of approximately 30 cm on either side of the main shank. The front shanks effectively shatter the soil to a depth of approximately 30 - 40 cm while the back shanks shatter to a depth of 50 - 60 cm.

The ease of soil shattering varied markedly from farm to farm. On those farms with good management, i.e. crop rotation and application of manures, soil clods were smaller and more friable. Heavy construction which resulted in severe soil mixing also affected the effectiveness of subsoiling. Areas, such as at the Brooke Valve, were so hard that the subsoilers could not be pulled deeper than about 40 cm.

Crop Monitoring (1982)

Table 1 summarizes the 1982 crop monitoring program for soyabeans. Similar results were compiled for corn, winter wheat, barley and oats. The soyabean data is reported here to illustrate the general trends observed with the remaining crop types.

The trench or pipeline areas reflects the greatest difference with variance from the field ranging from a low of 7 percent to a high of 84 percent. This latter figure is associated with a site which has severe drainage problems. The plot with the low variance is identified with a property that has a high level of management and a concern by the owner for the improvement of the pipeline and right-of-way section.

The results associated with the "travelled" portion of the right-of-way shows, in general, a narrower range of variances with some plots approximating the field conditions. Excluding plot # 113, the results of the sampling indicate that the majority of the right-of-way plots lie within 0 - 12 percent variance range.

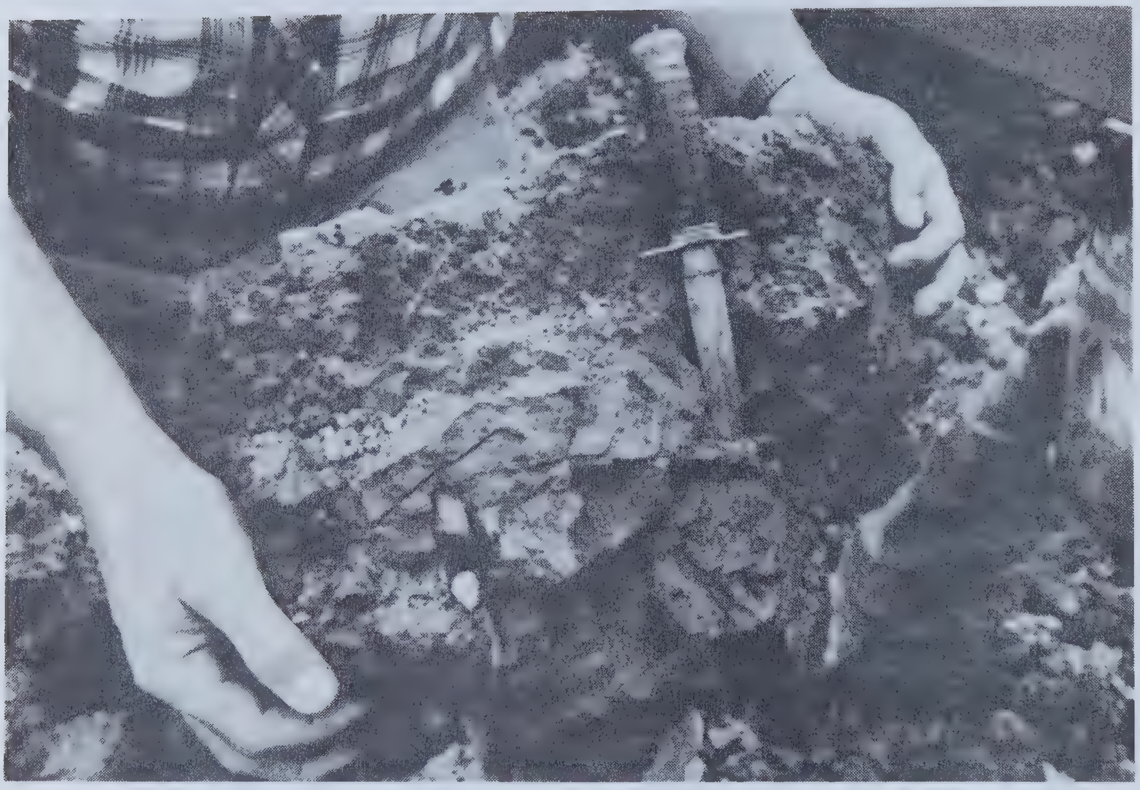


FIGURE 6: SOIL CLODS

A close-up view of the soil clods which were lifted by the subsoiling action.

TABLE 1: CROP MONITORING DATA FOR SOYABEANS - 1982

Plot Number	Sample Location	Row Width (cm)	Height Plant (cm)	Calculated[1] Yield Kg/Hectare	Per Cent[2] Difference from Field Sample	Population Plants per Square Foot (930 cm^2)	Bean[3] Straw Ratio	Pod Distribution[4] Per Cent	
								2 Bean	3 Bean
001	Pipeline	18	31-38	51.8	22.69	3.9	1.20	41	48
	R.O.W.		38-46	62.7	6.42	4.6	1.31	40	45
	Field		51-61	67.0	-	5.6	1.03	43	51
003	Pipeline	51	20-31	20.1	56.40	2.2	1.03	62	27
	R.O.W.		46-51	35.3	23.43	3.1	1.25	45	45
	Field		51-61	46.1	-	3.5	1.42	44	40
004	Pipeline	51	20-31	21.6	47.32	2.9	1.15	62	27
	R.O.W.		41-46	37.4	8.78	3.9	1.26	51	37
	Field		46-51	41.0	-	3.7	1.29	45	37
010	Pipeline	36	20-31	12.9	54.09	4.2	.50	60	23
	R.O.W.		31-38	28.1	-	4.4	.83	37	50
	Field		31-38	28.1	-	5.4	.72	50	38
011	Pipeline	53	31-38	31.7	28.92	2.3	1.15	38	52
	R.O.W.		38-46	41.8	6.28	3.2	1.18	35	55
	Field		51-61	44.6	-	3.9	1.21	44	47
053	Pipeline	53	41-46	43.9	7.77	4.2	1.35	40	34
	R.O.W.		46-56	43.9	7.77	3.6	1.24	44	41
	Field		56-61	47.6	-	4.0	1.10	37	46

TABLE 1: CROP MONITORING DATA FOR SOYABEANS - 1982

Plot Number	Sample Location	Row Width (cm)	Height Plant (cm)	Calculated[1] Yield Kg/Hectare	Per Cent[2] Difference from Field Sample	Population Plants per Square Foot (930 cm^2)	Bean[3] Straw Ratio	Pod Distribution[4] Per Cent	
								2 Bean	3 Bean
061	Pipeline	53	38-46	28.8	39.24	3.6	1.02	49	37
	R.O.W.		46-51	47.4	-	3.6	1.10	39	52
	Field		51-61	47.4	-	3.4	1.03	41	49
110	Pipeline	36	46-51	47.4	15.51	5.3	1.22	35	53
	R.O.W.		51-56	49.7	11.41	5.7	1.12	43	46
	Field		56-61	56.1	-	5.0	1.06	36	51
113	Pipeline	53	15-20	8.6	83.40	1.5	.75	50	28
	R.O.W.		20-31	13.7	73.55	2.2	.82	49	26
	Field		61-71	51.8	-	4.2	1.20	31	62

[1] Field sample plot - laboratory weight data converted to a weight area basis.

[2] Difference from the field sample (control) location

[3] Relationship of weight of straw to weight of bean.

[4] Distribution of 2 and 3 bean pods in the sample.

The height of the crop among the various properties is also variable as well as between the pipeline and the field. The contrast in height of the crop provides the greatest visual impact between the pipeline and the field. The data on crop heights indicate that in many of the plots the crop on the pipeline or trench is only half as high as the crop on the field. The visual difference between the right-of-way is also variable, with a variance or spread of values in crop heights from 15 - 17 cm. The data show that most of the plots on the right-of-way have crop heights ranging from 38 - 51 cm (15-20 inches). The variation in heights between field plots ranges from a low of 30 cm to a high of 86 cm. However, taking the individual properties, the difference between right-of-way and field samples is often a matter of only a few centimetres.

The data on plant population generally indicate that there is a higher plant population in the field. It also reflects the higher plant population with respect to the planting of narrower row widths. The four plots on which higher population values are reported is inconsistent and is believed to have resulted from the inclusion of some small suppressed plants in the sample count, or the inclusion of branches that may have become detached in transportation and handling that has exaggerated the count.

The difference in plant population between the pipeline, right-of-way and field is identified with plant mortality at the emergence and seedling stage. The variation in plant population between the field plots on the different properties reflects differences in seeding rates as well as the impact of plant competition.

The data on the bean-straw ratio, the weight of beans per plant and the average number of pods per plant, although showing some inconsistencies, generally reflect that the plants on the field have a higher bean-straw ratio, a higher weight of bean per plant and a higher number of pods per plant than the trench area or right-of-way. Further, the plants on the right-of-way and field have a higher preponderance of "three bean" pods than those over the trench.

Field examination of root systems of plants over the trench with those on the field consistently showed a shallow, stunted, root development network. This restricted rooting problem is reflected in the suppressed plant growth, yield and other characteristics identified with the plants on the pipeline.

The lower plant population on the trench or pipeline area, combined with shorter plants and fewer number of pods, has resulted in lower yield figures and higher per cent variances.

Crop Monitoring (1983)

The 1983 crop monitoring program has provided the first opportunity to evaluate the benefits of the subsoiling program. A crop monitoring program similar to 1982 was continued during the current year and preliminary results of this program are presented here. Observations made in the spring on winter wheat showed that in general the area over the subsoiled portion of the right-of-way exhibited considerably more vigor and was also much higher then the non-subsoiled portion of the right-of-way. Similar observations were made on the corn and soybean crops indicating that the health and vigor of a plant over the subsoiled portion of the right-of-way were much superior to those on the untreated areas of the right-of-way.

Yield data from two plots containing winter wheat indicate that a 20% - 50% increase in yields can be anticipated. Although yield data is not available at the present time for soybeans or corn, it would appear as though an increase in crop yields can also be expected.

SUMMARY AND CONCLUSIONS

Soils along most of the Dawn-Kerwood pipeline loop show limited variability. They consist of clay textured, lacustro-till soils that have relatively flat topography.

The major impacts of pipeline construction have been on soil physical properties, such as soil structure, drainage and aeration rather than chemical ones. Root penetration over the trench is restricted to the plow layer. Until problems with the soil physical properties are resolved continued reductions in crop yield of 30% - 40% can be expected. Initial test results suggest that subsubsoiling can effectively ameliorate adverse soil physical conditions and improve crop yields.

The spacial extent of the surface drainage problem shows up very clearly after heavy rains when surface runoff collects in depressional areas and creates local pondings. In their dry post-cultivated state, these depressions are not discernible to the human eye and may only be a few cm in depth. The surface water problem can be attacked in two ways, namely, land levelling and/or surface furrowing. These must go hand in hand to be effective in solving the issue of surface drainage. Another area which requires attention is ensuring that the outlets of the field surface drainage are below grade and kept open and cleaned.

While tile drainage can improve and control soil moisture conditions it cannot be expected to handle surface runoff and the accumulations that occur in depressional sites on the heavy clay soils found in this region. Some open ditch, surface drains required.

Several key points are also evident from the crop monitoring program.

- -The travelled part of the right-of-way has almost been restored to an equivalent yield level after seven years.
- -A significant reduction in crop yield occurs immediately over the trench area for both the 42 and 34 inch pipelines. Even after 25 years portions of the 26 inch line still show evidence of yield reductions. This is understandable, since no special environmental or amelioration practices were done at that time.
- -Of the crops encountered, soybeans and white beans are the most sensitive to yield depressions. Even after seven years, soybean yields are 40% - 50% lower over the trench area as compared to the undisturbed field conditions. With good management practices this can be reduced to 20% or less.
- -The reduction in crop yields, plant height and mortality rates can be related to soil factors. The most prominent soil factors are those that restrict rooting depth such as adverse soil structure and the associated occurrence of hydromorphic conditions. The wet conditions can also lead to oxygen deficiencies (anaerobic conditions) which affect the availability and uptake of plant nutrients. In addition, the crusting of the soil due to a lack of organic matter to maintain a friable, open surface soil causes a reduction in yield.
- -Amelioration practices should be directed toward improving rooting depth and aeration of the rooting zone. This can best be achieved through a combination of deep tillage or subsoiling and a cropping program which emphasis deep rooting legumes and the addition of organic matter by green manure crops or animal manures.

APPLICATIONS OF REMOTE SENSING TO LAND RESTORATION AFTER PIPELINE CONSTRUCTION: ONTARIO CASE STUDY

V. Singhroy
Research Engineer
Ontario Centre for Remote Sensing
Ministry of Natural Resources
880 Bay Street, 3rd Floor
Toronto, Ontario M5S 1Z8

ABSTRACT

The development and implementation of land rehabilitation measures to reduce the impact of pipeline construction on agricultural crop yield and river crossings require systematic data collection and monitoring programs. This paper reports on the use of remote sensing data as an effective method of monitoring construction and post-construction activities and of supporting field data collection for several types of land rehabilitation programs.

Colour infrared and normal colour aerial photography, as well as video coverage, was acquired over several agricultural areas and river crossing sites in Southern Ontario before, during and after construction of a 42-inch gas pipeline. Conclusions were drawn as to the respective contributions which satellite and airborne remote sensing data can make to mapping land use/land cover along pipeline corridors, to monitoring the impact of construction on crop productivity, and to monitoring clean-up operations and bank stabilization measures at river crossings.

INTRODUCTION

When the biologically active surface layer of the soil is disturbed by the construction of energy network grids, various measures are required to restore the soil to its original productivity. For instance, the construction of a cross-country pipeline involves the stripping of top soil, the trenching of subsoil, stockpiling, pipe installation, trench refilling, topsoil replacement and the re-connection of farm drains and fences. The disturbance from this sequence of operations can greatly reduce the productivity of agricultural soils. Analyses of soil and crop data along recently constructed pipelines in

Ontario have shown a decrease in crop yield ranging from 20 to 40 percent (Eccles, 1979; Shields, 1979); increases in potential soil densities ranging from 1600 to 1700 kg/m^3 (Quigley, 1979); and a decrease in the rate of infiltration ranging from 0.9 to 4.3 m/day (Union Gas, 1983). The impacts of soil compaction resulting from the vibration of heavy construction vehicles is one of the many factors responsible for decreases in crop yield (Swanson and Jacobson, 1956; McKyes, 1977). At river crossings, cut-and-fill operations, slope grading at river banks and subsequent riverbed dredging often result in water quality degradation and post-construction bank erosion. These construction operations and their impacts need to be monitored systematically for the development and implementation of land restoration programs. This paper reports on the use of remote sensing data as an effective source of information in the planning and monitoring of the construction process and post-construction restoration programs, and of supporting field data collection.

PLANNING OF PIPELINE CONSTRUCTION AND LAND RESTORATION

Remote sensing data offer unique advantages in all phases of the land restoration process. At the route planning phase, airborne and satellite data have been used in conjunction with other geological and geotechnical data to select the most environmentally stable route, and to avoid ecologically sensitive areas. Mollard (1956, 1959, 1972), Union Gas (1981) and Trans Canada Pipelines (1981), have used large-scale black and white airphotos and related field studies to plan several pipeline routes. Spring colour infrared and normal colour photography together with enhanced or digitally classified LANDSAT data has proven the most valuable combination for pre-construction reconnaissance mapping (Singhroy, 1983). The parameters studied by remote sensing include terrain and engineering materials, surface and subsurface drainage, moisture and field conditions (Figure 1), and land cover information. Multispectral data obtained at the appropriate time can produce timely land cover and satellite thematic maps, and can aid in identifying suitable foundation material, as well as in locating unsuitable areas, such as those with a high water table and particularly sensitive areas for river crossings. Geometrically corrected 1:250,000-scale LANDSAT MSS, and thematic mapper colour composites and SEASAT SAR data also permit an accurate updated interpretation of the current regional engineering terrain information normally required for public hearings and for planning alternative routes. The spectral classification of multitemporal LANDSAT MSS and thematic mapper data is useful in providing accurate and timely hard-copy thematic land cover colour maps at scales of

1:100,000 and 1:50,000 (Singhroy, 1983). These LANDSAT-based thematic maps are particularly useful in planning land restoration programs on the affected land cover.

The locating of drainage tiles in the poorly-drained areas of Southern Ontario is sometimes a major problem for pipeline companies. A large-scale spring colour infrared photograph (Figure 2) was used to detect tile drainage on the heavy Brookston clay near Strathroy. On the spring infrared photographs the drainage tiles appear as distinct parallel lines, while at the time of crop emergence, they appear as parallel red lines indicative of vigorous growth associated with the well-drained areas.

CONSTRUCTION AND POST-CONSTRUCTION MONITORING

Large-scale aerial imagery (70 mm stereo photography, oblique photography or airborne video recording) is the most practical and economical means of construction and post-construction monitoring. Both regulatory agencies and pipeline companies use such imagery for environmental assessment and to monitor ground operations and progress. The large-scale (1:10,000-scale or larger) 70 mm stereo transparency format is generally used to perform stereoscopic analysis and area, distance and height measurements which are sometimes required for engineering studies and litigation processes.

River Crossings and Bank Stability

At river crossings the increase in suspended sediment resulting from dredging (Figure 4) is an important water quality concern. Martz (1980) noted a 36% increase in suspended sediment resulting from construction activities in a minor stream. Moncrieff (1981) noted significant damage to benthic communities downstream of a crossing on the Thames River. In addition, unprotected riverbanks are potentially unstable areas because of continuous downslope and sometimes basal erosion. The gradual softening of soil mass and the resultant decrease in in-situ mass strength of the soil can sometimes result in slides on the unprotected riverbank. Figures 3, 4 and 5 are examples of 1:10,000-scale 70 mm colour infrared coverage taken for environmental assessment, before, during and after construction at the Nith river crossing. When pipe installation and grading are completed at river crossings, environmental regulations require that riverbanks be restored to their original contours. This involves the replacing of excavated soils with fill, followed by seeding with a legume-grass mix, and subsequent mulching. Figure 5 illustrates the use of spring colour infrared photography to monitor the early growth condition of the new vegetation on the banks of the Nith River. Figures 6 and 7 are normal colour stereo photos of the results of stability measures and mulching done soon after construction at the Thames and Credit rivers.

Monitoring Rehabilitation of Compacted Soils

One of the important factors contributing to a reduction in crop yield along the right-of-way is significant change in the physical and chemical properties of the soil (Quigley, 1979; Shields, 1980; DeJong, 1973). The major cause is compaction caused by the vibration of heavy equipment during construction. As a result, soils along the rights-of-way are quite dense, having a low inflation rate and a low moisture content (Table I). The infrared photograph (Figure 8) shows the low moisture of the compacted zone of pipeline constructed during 1957, 1966 and 1982. Moisture deficient areas appear as light-toned lines on the infrared photography. The compacted soil inhibits penetration by roots and water. In depressions, an iron pan is formed below the A horizon, as a result of fluctuating water levels and movements of dissolved iron over the compacted material (Figure 9). The use of a subsoiler is recommended to break up the iron pan and loosen the compacted soil (Moncrieff, 1983).

The Ontario Centre for Remote Sensing and Union Gas Limited are currently using 1:10,000-scale colour infrared photography to monitor the productivity of soils along recently-constructed sections of pipeline in Southern Ontario. The following is a summary of the monitoring process.

1. During construction, colour infrared photography was used to provide a permanent record of topsoil conservation and to assess the vigour of the crop along the right-of-way.

2. During the spring months following construction, the infrared images were used to locate drainage tiles and to identify those that had been clogged or ruptured during construction. In addition, local ponding due to soil compaction and ruts caused by vibration from heavy vehicles were identified, as well as a variety of moisture-related patterns.

3. Photography taken during the growing and maturing periods was used to monitor crop development and to identify problems contributing to reduced yields. Such problems included soil erosion (Figure 10), moisture stress, weed infestation,

disease and insects. The uniformity of crop ripening and the variations in yield were also identified from sequential colour infrared photography.

In general, all crops within the right-of-way were observed to be growing poorly (Figures 11 and 12). As expected, clay soils were more compacted than sandy soils. Extreme cases of poor growth were observed in mixed grain, corn and pasture grown on heavy clay soils. The same crops perform better on well-drained sandy soils. Subsoiling was carried out to break up the compacted zones under the Berrien sandy loam, thereby resulting in good growth of the tobacco cover crop (Figure 13).

RECOMMENDATIONS

If rehabilitation means the process of returning the variety of soil types disturbed by the construction of a gas pipeline to a condition that conforms with prior land use, then the complementary use of a variety of remote sensing data types is an efficient means of monitoring and measuring the rate of improvement. The uses of multitemporal, multiscale airborne and satellite data have been demonstrated in this paper. Table II provides a short list of recommended remote sensing data types useful to be used in each phase of the restoration process.

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DESCRIPTION OF FIGURES

Figure 1:	Spring Colour Infrared (CIR) photograph (scale 1:10,000) showing surface moisture distribution and water-holding condition of the Haldiman clay loam along the pipeline corridor.
Figure 2:	Spring CIR photograph (scale 1:10,000) showing tile drainage on heavy Brookston clay, at "A" and "B". Pipeline construction is shown at "C".
Figure 3:	CIR photograph (scale 1:10,000) showing morphology of river banks before pipeline crossing: Nith River, Southern Ontario.
Figure 4:	CIR photograph (scale 1:10,000) showing suspended sediment dispersion downstream during construction from crossing at Nith River.
Figure 5:	Late spring CIR photograph (scale 1:10,000) showing revegetation and bank stability condition after pipeline crossing of Nith River.
Figure 6:	Normal colour photograph (scale 1:10,000) showing bank stability measures at Credit River crossing.
Figure 7:	Normal colour photograph (scale 1:10,000) showing bank stability measures at Thames River crossing.
Figure 8:	CIR photograph (scale 1:10,000) showing compacted zones of three different pipeline construction sites: "A" - 26", 1957; "B" - 34", 1966' "C" - 42", 1982.
Figure 10:	CIR photograph showing soil erosion of Berrien sand along pipeline right-of-way.

TABLE I

Soil Moisture Content (% by weight) along Dawn-Kerwood Loop Pipeline
(After Ecological Services for Planning Ltd., 1983)

A. 0-20 cm depth

		Right-of-Way		
Farm	Control	42	mid 42	36
1.	35.83	29.03	34.80	27.68
2.	28.21	24.48	27.10	24.86
3.	18.61	18.51	26.68	22.78
4.	30.48	23.60	24.34	21.96

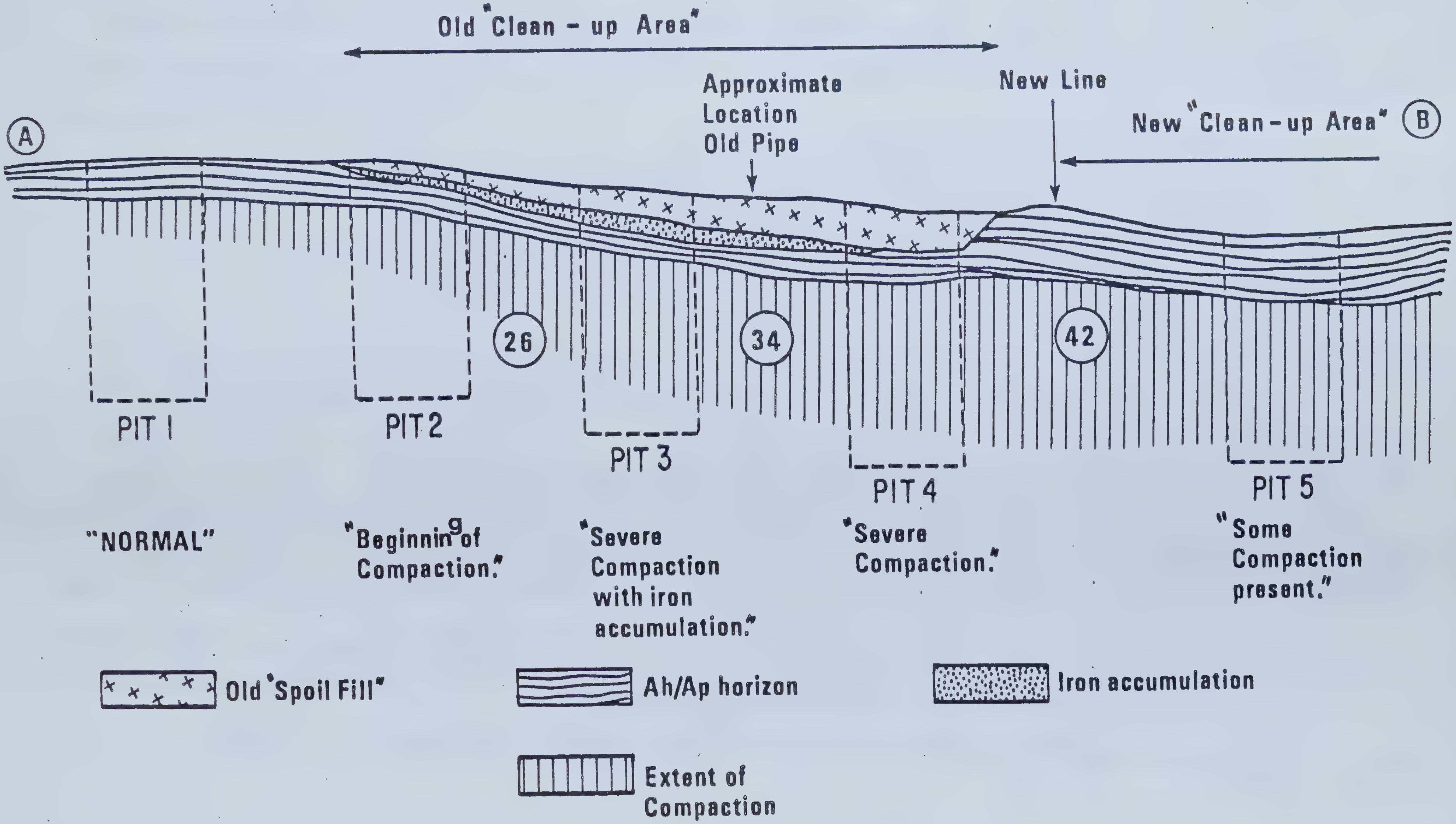
B. 20-40 cm depth

Farm	Control	42	mid 42	36
1.	-	-	-	-
2.	26.67	21.78	26.22	26.32
3.	19.14	21.25	16.66	17.88
4.	29.48	23.61	22.70	23.57

TABLE II RECOMMENDED MULTIDATE REMOTE SENSING DATA IN SUPPORT OF REHABILIATION PROGRAMS RELATED TO PIPELINE CONSTRUCTION

APPLICATION	PRE CONSTRUCTION	DURING CONSTRUCTION	POST CONSTRUCTION
1. AGRICULTURAL AREAS: Objective: (A) To minimize impacts on agricultural soils and crops. (i) to conserve top soils (ii) to avoid unnecessary soil compaction and rotting caused by heavy vehicles (iii) to locate and repair tile and clogged drainage (v) to monitor crop vigour/stress before and after construction in relation to yield estimates. (vi) to identify agriculture land uses	LAND COVER INFORMATION: Regional land cover thematic map of pipeline corridor from classification of LANDSAT & TM data Mid-August scene is recommended for separation of the major agricultural land cover; Early summer scene provide improved recognition of soil/crop contrast and sharper discrimination of regional soil boundries. Medium to large scale black and white and normal colour aerial photographs; to map detailed land cover; to assist in discussing cover conditions at public hearings. Aerial video and obliques: to update historical records; Early spring colour infrared, Scale 1:10,000,70mm or 9" x 9" stereo format: to locate tile drainage; to map the distribution of soil moisture; to identify localized ponding;to establish general field conditions; to discriminate soil boundaries	CONSTRUCTION PRACTICES: Aerial video, obliques and stereo format: 9" x 9" or 70 mm 1:10,000 scale colour infrared and normal colour; to monitor construction practices - top soil stripping, trenching, at refilling and clean-up operations; to evaluate field conditions at the time of construction.	SPRING: 70 mm stereo, colour infrared scale 1:10000; to locate damaged tile and clogged drainage; to identify areas of surface ponding; to evaluate field condition at the time of seeding; to monitor moisture distribution over compacted zone. Mid-June: Colour infrared (70 mm.); to inspect crop germination success emergence and problems related to early stages of growth. July-August: Colour infrated (70 mm); to assess crop development, maturity, vigour and yield variation in relation to rehabilitation practices - fertilizers, subsoilers, etc.
2. RIVER CROSSINGS: Objective: (A) to minimize impacts on river banks and water quality. 1. To monitor revegetation and other bank stability practices 2. To monitor production and dispersion of sediment during construction.	Early spring, normal colour, 70 mm stereo format, scale 1:10,000 aerial photographs; to measure bank full stage, over bank flooding and erosion and sedimentation processes at river crossing.	Normal colour and colour infrared 70 mm stereo format, scale 1:10,000; to monitor construction practices and sediment dispersion down stream from crossing.	70 mm colour infrared scale 1:10,000; to monitor revegetation and other bank stability measures.

FIGURE 9: Diagram Showing Zone of Compacted Soil on Pipeline Right-of-Way (Van den Broek, 1982)


Old "Clean - up Area"
Approximate Location Old Pipe
New Line
New "Clean-up Area"
A
B
26
34
42
PIT 1
PIT 2
PIT 3
PIT 4
PIT 5
"NORMAL"
"Beginning of Compaction."
"Severe Compaction with iron accumulation."
"Severe Compaction."
"Some Compaction present."
Old "Spoil Fill"
Ah/Ap horizon
Iron accumulation
Extent of Compaction

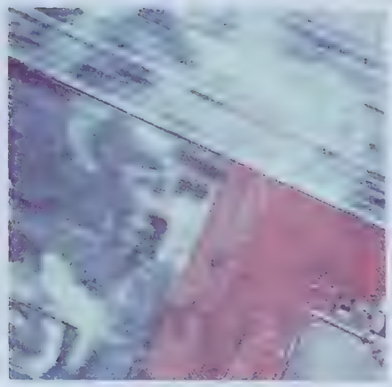


FIG 1

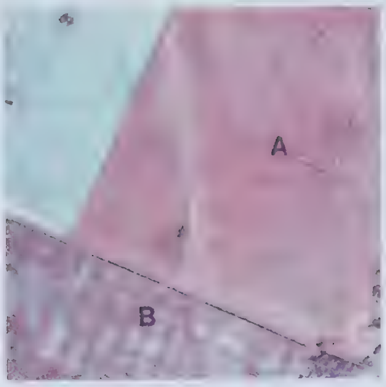


FIG 2

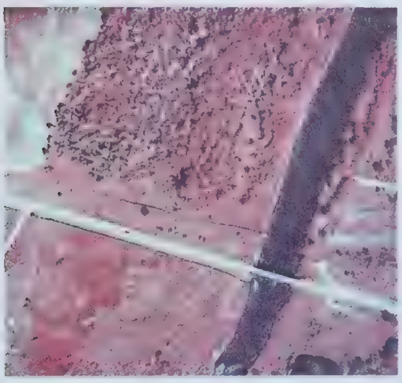


FIG 3

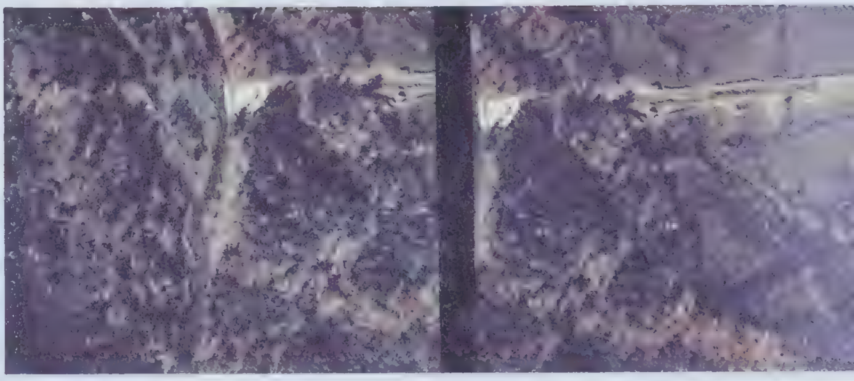


FIG 6

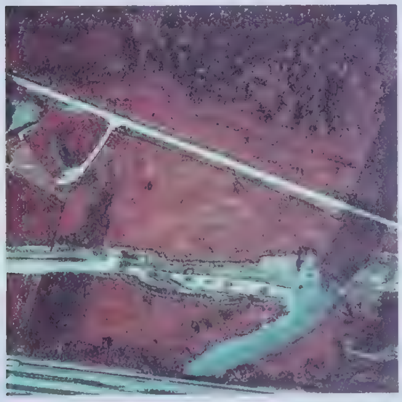


FIG 4

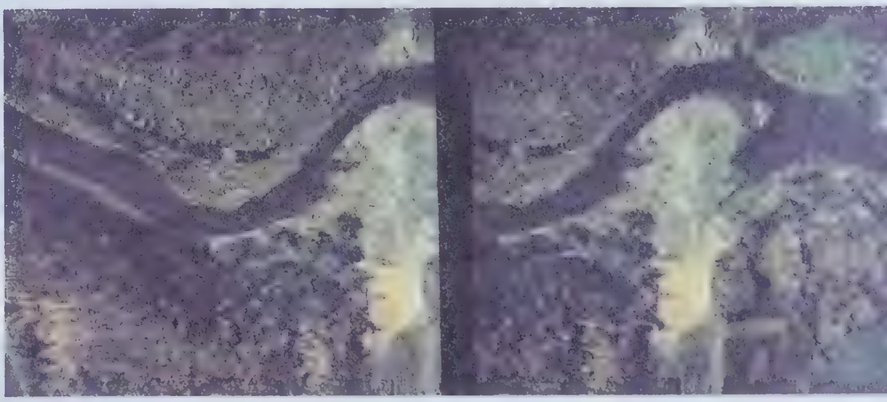


FIG 7

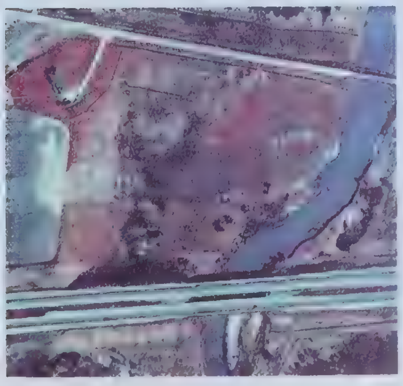


FIG 5

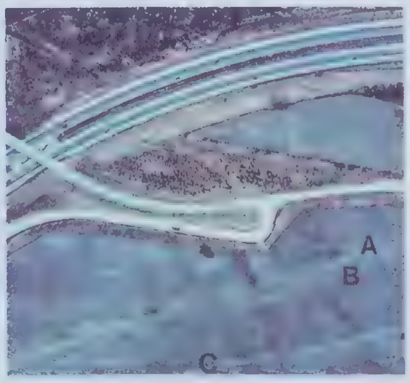


FIG 8

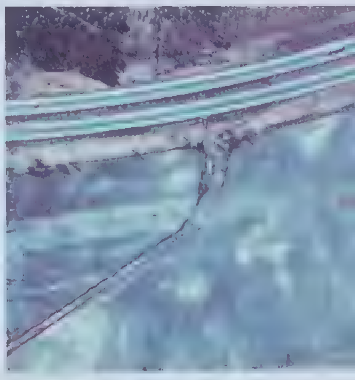


FIG 10

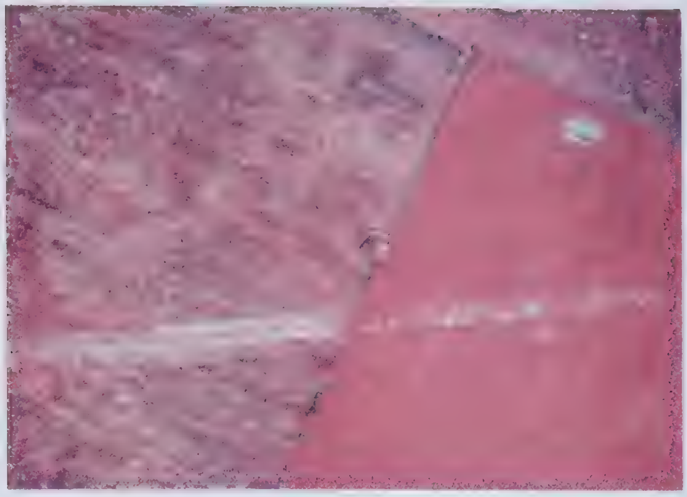


FIGURE 11: CIR photograph showing the effects of soil compaction on the performance of winter wheat and pasture.

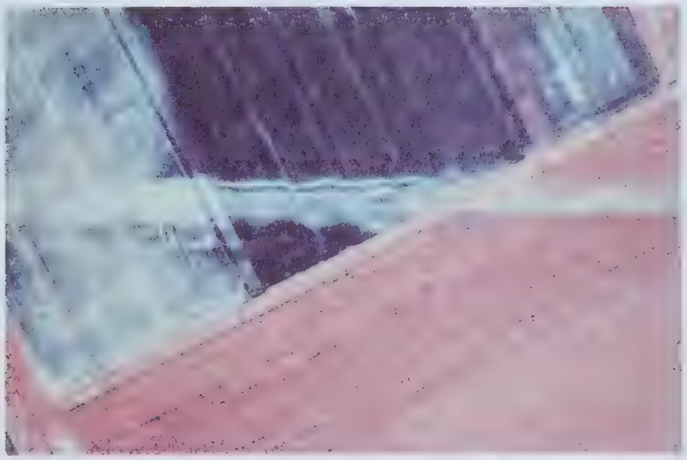


FIGURE 12: CIR photograph showing the effects of soil compaction on the performance of corn.

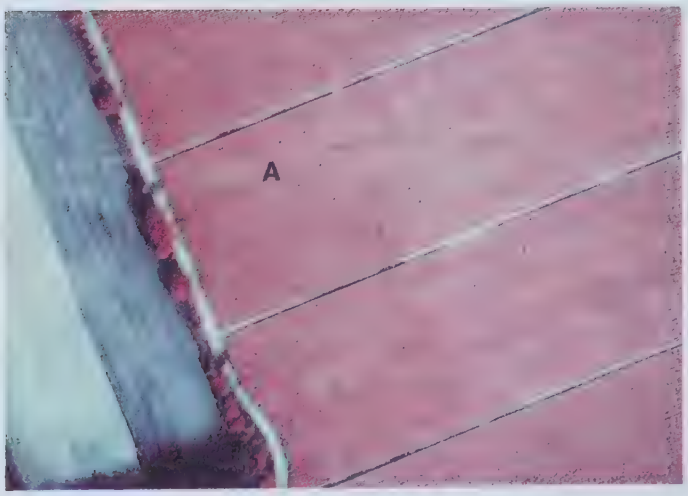


FIGURE 13: CIR photograph showing good performance of tobacco crop after the compacted zone of the Berrien sandy loam has been broken by a subsoiler. "A" indicates area of pipeline construction.

SESSION III-C

RECLAMATION/EROSION CONTROL

Dr. G.K. Rutherford - Chairman

REVEGETATION AND RECLAMATION OF SANDY REGOSOLS

- A Preliminary Assessment -

D. A. LLOYD

Reclamation Coordinator, Public Lands Division
Alberta Department of Energy and Natural Resources
Edmonton, Alberta

S. SMOLIAK

Research Scientist, Plant Science Department
Lethbridge Research Station
Agriculture Canada
Lethbridge, Alberta

ABSTRACT

The paper presented here documents the preliminary results of drill seeding native and introduced grass and legume species into a plot that has been fertilized by deep banding. A mulch treatment was simulated by killing existing surface vegetation with glyphosphate (trade named "Roundup"). The study goal was to determine which test species grew more favorably on an amended sandy regosol in southeastern Alberta and to determine subjectively the effectiveness of deep banding fertilizer.

Though all seeded species germinated in late fall (1982) and early spring (1983) early summer (1983) grass growth assessment indicated that russian wild ryegrass (Elymus junceus var. "Swift"), two varieties of crested wheatgrass (Agropyron desertorum var. "Nordan" and Agropyron cristatum var. "Fairway") and slender wheatgrass (Agropyron trachycaulum var. "Revenue") produced the most favorable growth. Alfalfa (Medicago sativa var. "Drylander") produced a continuous steady germination and growth rate ranging mostly from 75%-95% despite rabbit and deer browsing. Hard fescue (Festuca ovina var. "Durar"), slender wheatgrass and the two varieties of crested wheatgrass were the only grasses which grew with alfalfa. However, alfalfa heavily dominated the grass legume mix. Cicer milkvetch (Astragalus cicer var. "Oxley"), proved a better legume for allowing a greater percentage of grass growth in a legume-grass mix. Six grass species -- russian wildrye (Elymus junceus var. "Swift"), hard fescue, slender wheatgrass, the two crested wheatgrass varieties and northern wheatgrass (Agropyron dasytachum var. "Elbee") grew well with cicer milkvetch.

I INTRODUCTION

Many sandy areas occur throughout southern Alberta. When these sandy soils are disturbed, vegetation that has been damaged or eliminated is difficult to re-establish. The factors wind erosion, low moisture availability combined with high soil surface temperatures and low nutrient status usually preclude successful regrowth or revegetation efforts on any disturbed sandy sites. Because sandy soils are difficult to revegetate, the study outlined below was developed to determine which grasses and legumes would grow most favorably on a sandy regosol that had been amended by deep banding specifically chosen fertilizers. The study was also to subjectively assess the effectiveness of deep banding different fertilizer applications.

II SITE DESCRIPTION

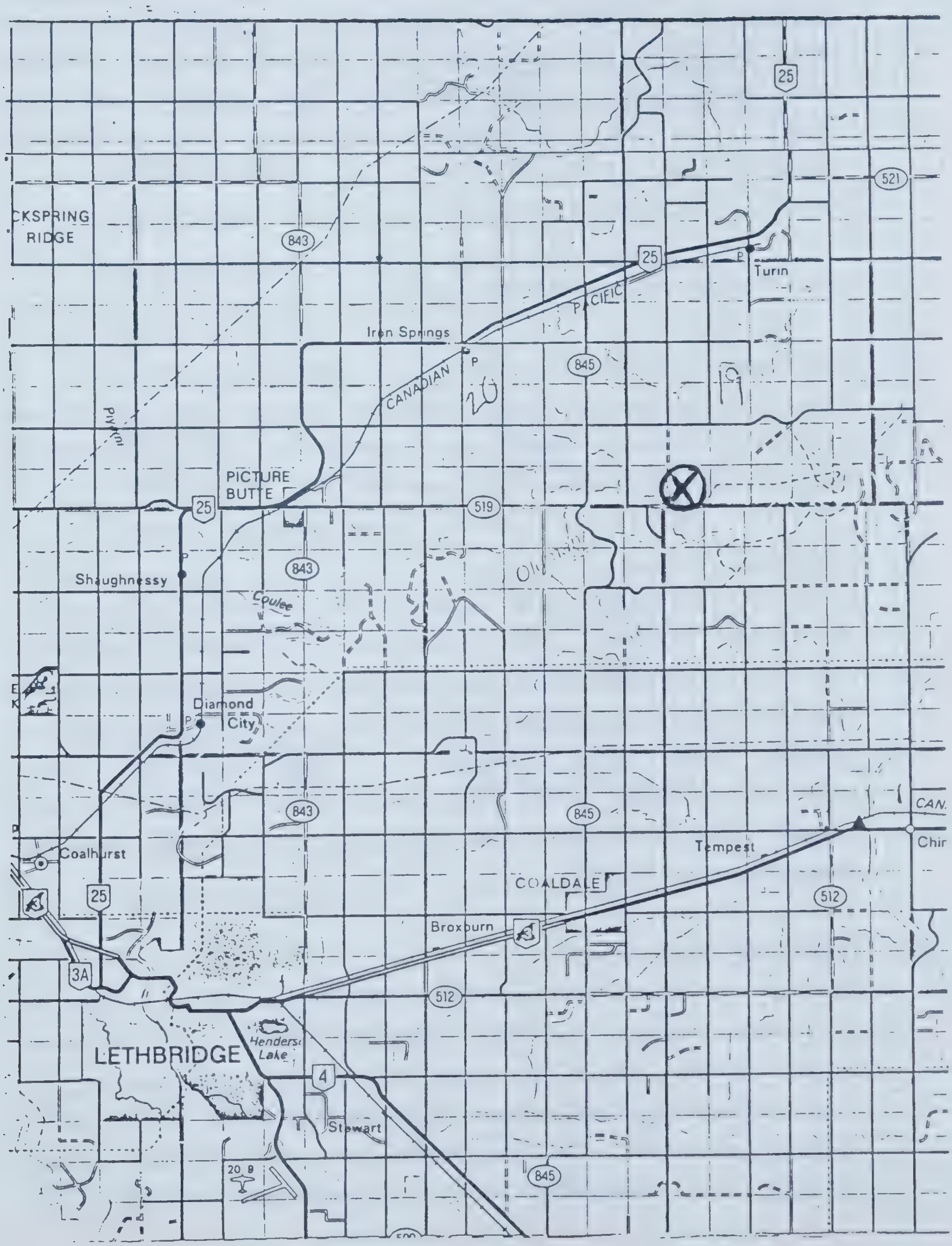
A. Location

The study location chosen is a mile and half north of the Old Man River at SE 5-11-19-W4. The surrounding area is shortgrass prairie which supports cattle grazing for about 2 weeks to one month of the year depending on vegetation success. The exact plot site is slightly depressional with a moderate downward northeast slope of about 5%. Figure (1) shows a map location of the site.

B. Soil

The soil is classed as an Orthic Brown Regosol. A three to four inch fine gravel lens occurs fifteen inches deep. Surrounding gravel ridges and exposed sandy outcrops are scattered throughout the area. The terrain has a gently rolling relief.

Figure 1


CKSPRING
RIDGE
843
25
521
Turin
P
PACIFIC
Iron Springs
CANADIAN
845
20
19
Piyami
PICTURE
BUTTE
519
Shaughnessy
Coulee
Oldman
Diamond
City
843
845
CAN.
Chin
Tempest
Coalhurst
COALDALE
512
Broxburn
3A
512
LETHBRIDGE
Henders
Lake
4
Stewart
20 B
845

C. Vegetation

The site is typically a Stipa-Bouteloua native grassland range type.

Speargrass (Stipa comata), bluegrama (Bouteloua gracilis), sandgrass or sandreed grass (Calamovilfa longifolia) and june grass (Koeleria cristata) are the dominant grasses. Prickly pear (Opuntia polyacantha) and rose (Rosa woodsii) are also common to the site. Other native vegetation found on site are listed in Table (1).

III SITE PREPARATION AND DESIGN

1. Plot Layout

Three replications of eight different grasses and two legumes with five different fertilizer combinations were established. The plot layout is shown in Figure (2).

2. Herbicide Treatment

Prior to fertilizing and seeding, the plot area was sprayed May 14 and 18, 1982 with glyphosphate (tradenamed "Roundup"). The herbicide application was attempted to eliminate existing growing vegetation and yet retain root material to simulate a crimped mulch straw treatment. A heavy dose of 1 part herbicide and three parts water was applied by a six foot boom sprayer mounted on a bicycle wheel and a hand held stainless steel tank application.

3. Fertilizer Application

The bulk of the fertilizers used was deep banded to a depth of six inches on May 17, 1982. The deep banding occurred seven inches to the side of the seed row 1 day before seeding. A small surface application was also applied prior to the drill seeding operation. The five fertilizers were applied randomly on each plot. Replicate one is illustrated in Figure (3).

Table 1

NATIVE VEGETATION

Scientific Name	Common Name
Poa secunda	Sandberg Bluegrass
Agropyron smithii	Western Wheatgrass
Carex filifolia	Sedge
Artemisia frigida	Pasture sagewort
Oxytropis sericea	Early yellow Loco-weed
Lithospernum incisum	Narrow-leaved puccoon
Antennaria dimorpha	Cushion everlasting
Erigeron caespitosus	Tufted fleabane
Liatrus punctata	Dotted blazingstar
Penstemon albidus	White beardtongue
Lygodesmia juncea	Skeletonweed
Chrysopsis villosa	Hairy golden-aster
Lomatium macrocarpum	Long-fruited parsley
Opuntia polyacantha	Prickly-pear

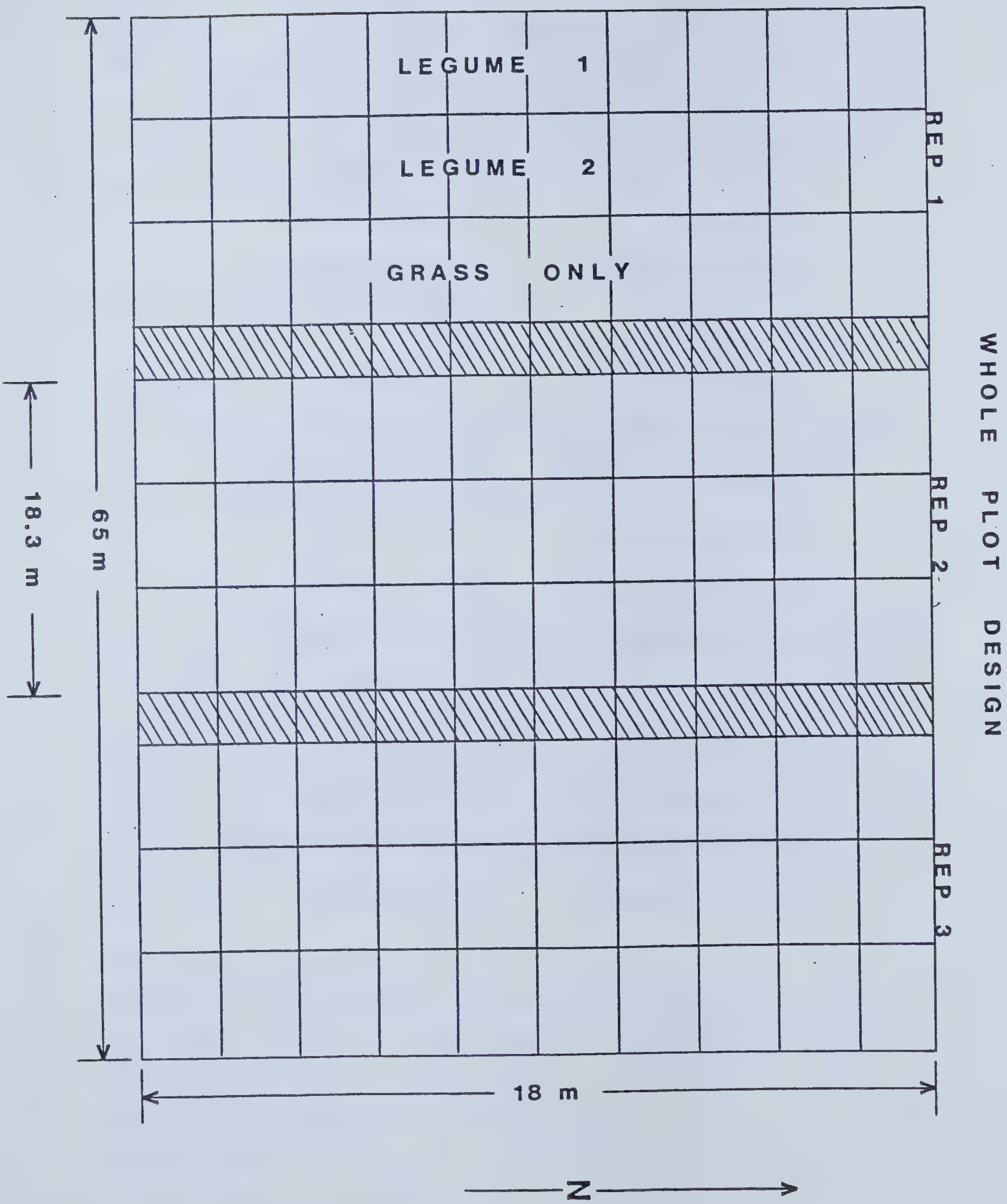
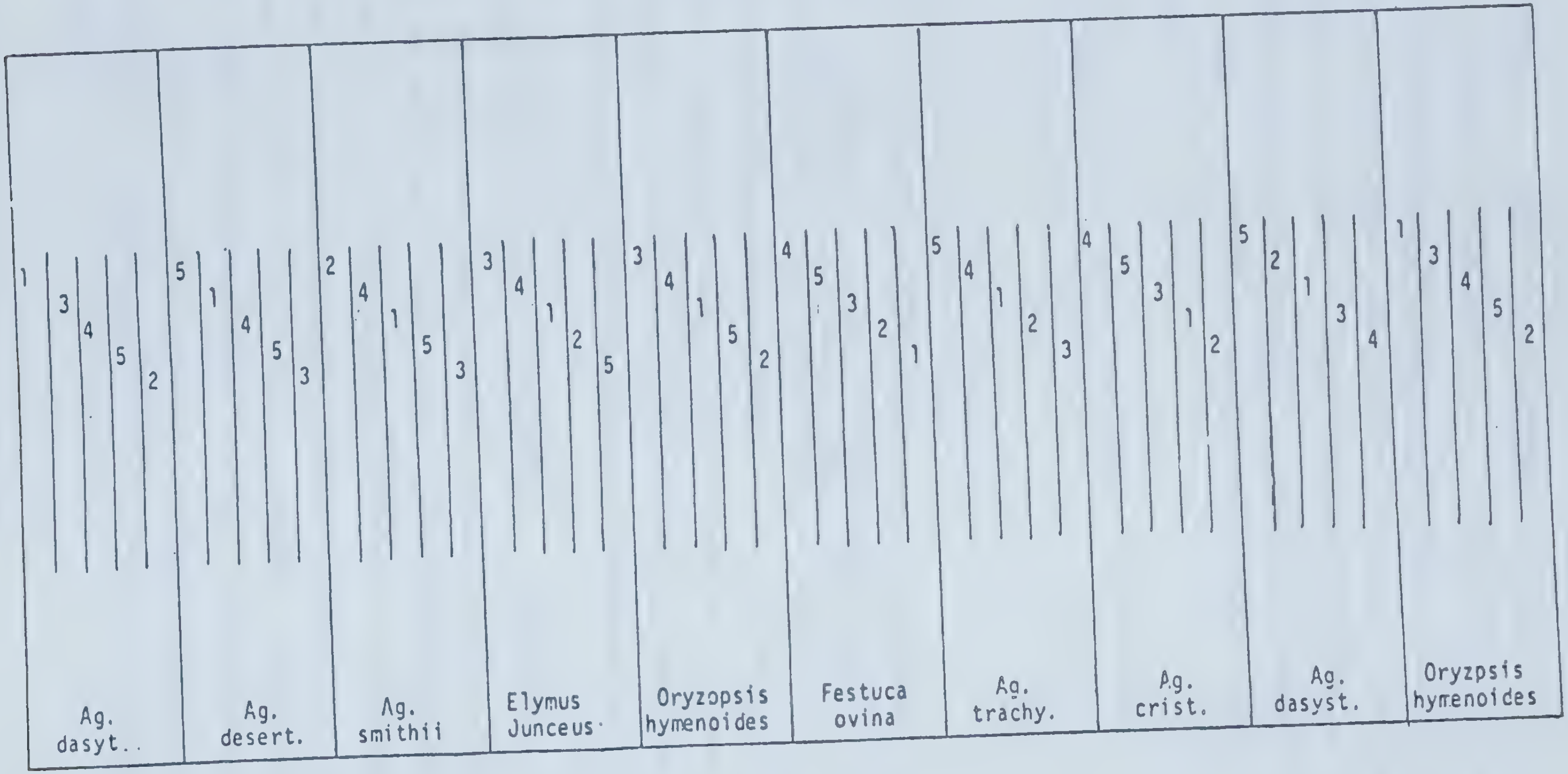

LEGUME 1
LEGUME 2
GRASS ONLY
REP 1
REP 2
REP 3
WHOLE PLOT DESIGN
65 m
18.3 m
18 m
N

Figure 3

REPLICATE NO. 1

SHOWING GRASS AND FERTILIZER

(LEGUME NOT SHOWN)


1 3 4 5 2
Ag. dasyt..
5 1 4 5 3
Ag. desert.
2 4 1 5 3
Ag. smithii
3 4 1 2 5
Elymus Junceus
3 4 1 5 2
Oryzopsis hymenoides
4 5 3 2 1
Festuca ovina
5 4 1 2 3
Ag. trachy.
4 5 3 1 2
Ag. crist.
5 2 1 3 4
Ag. dasyst.
1 3 4 5 2
Oryzpsis hymenoides

The fertilizers are represented by the numbers above and are as follows;

1 = 0-45-0 (triple superphosphate)
2 = 46-0-0 (urea)
3 = 32-0-0 (sulphur coated urea)
4 = 46-0-0 + 0-45-0 (urea + triple superphosphate)
5 = 32-0-0 + 0-45-0 (sulphur coated urea + triple superphosphate)

Figure (4) illustrates fertilizer placement spacing prior to the test and spacer grass seeding. Table (2) illustrates the fertilizers and application rates used.

4. Drill Seeding

A forage plot drill seeder developed by Agriculture Canada was utilized tp plant both the grasses and legumes on May 19, 1982. The seeder has a fixed depth gauge set at a 1/2 inch and a set of double wheel packers to firm the soil and help cover the seed. The machine is 1.8 meters wide and each seed row is set 18 cm apart. The test grass species were spaced every second seed box or 36 cm apart and a spacer grass (Agropyron cristatum - "Fairway" variety) was placed between every test grass to help separate fertilizer effects. Figure (5) illustrates the replicate configuration.

The seeding rate was based on the average number of seeds per pound required to plant 60 seeds per foot or 200 seeds per meter of row. The rates or grams per package established for each 18.3 meter species row is shown in Table (3). Two grasses were repeated for each replicate because two grasses that were originally designated for planting, Andropogon scoparius (little bluestem) and Calamovilfa longifolia (prairie sandreed), were too feathery to pass through the drill.

IV DATA COLLECTION

1) Weather Data

A tipping bucket rain gauge and a thermohygrograph (with humidity and temperature recordings), loaned by Environment Canada, each with a seven day recording capacity were set up on site to record temperature, humidity and rainfall. The humidity charts were abandoned halfway through the summer of 1982 because field mice destroyed the sensor hairs. Temperatures and rain results are shown in Table (4) for 1982 and 1983.

Figure 4

PLOT EXAMPLE

OF

FERTILIZER AND GRASS SPACING

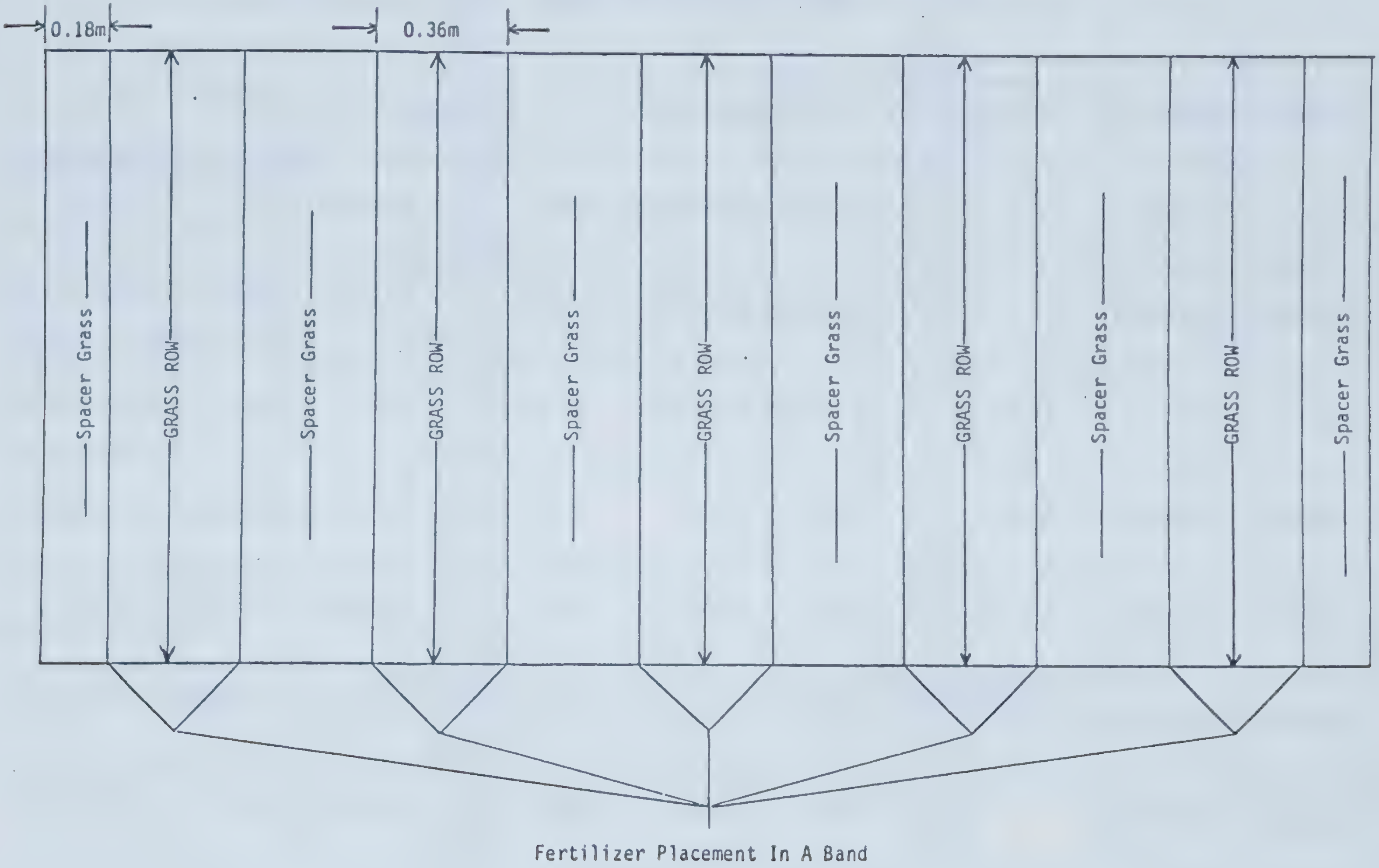

0.18m
0.36m
Spacer Grass
GRASS ROW
Spacer Grass
GRASS ROW
Spacer Grass
GRASS ROW
Spacer Grass
GRASS ROW
Spacer Grass
GRASS ROW
Spacer Grass
Fertilizer Placement In A Band

Figure 5

Randomized Species Placement on Whole Plot

REP 1 L_1	REP 1 L_2	REP 1 L_0		REP 2 L_1	REP 2 L_2	REP 2 L_0		REP 3 L_1	REP 3 L_2	REP 3 L_0
Agropyron	dasystachyum ALFALFA	- Elbee	▨	Agropyron	trachycaulum	- Revenue	▨	Oryzopsis	hymenoides	
Agropyron	desertorum	- Nordan	▨	Elymus	junceus	- Swift	▨	Agropyron	trachycaulum	- Revenue
Agropyron	smithii	- Rosana	▨	Oryzopsis	hymenoides		▨	Agropyron	desertorum	- Nordan
Elymus	junceus	- Swift	▨	Agropyron	dasystachyum	- Elbee	▨	Agropyron	smithii	- Rosana
Oryzopsis	hymenoides		▨	Agropyron	cristatum	- Fairway	▨	Festuca	ovina	- Durar
Festuca	ovina	- Durar	▨	Agropyron	desertorum	- Nordan	▨	Elymus	junceus	- Swift
Agropyron	trachycaulum	- Revenue	▨	Agropyron	smithii	- Rosana	▨	Agropyron	cristatum	- Fairway
Agropyron	cristatum	- Fairway	▨	Festuca	ovina	- Durar	▨	Agropyron	dasystachyum	- Elbee
Agropyron	dasystachyum	- Elbee	▨	Agropyron	trachycaulum	- Revenue	▨	Oryzopsis	hymenoides	
Oryzopsis	hymenoides		▨	Elymus	junceus	- Swift	▨	Agropyron	smithii	- Rosana

LEGEND: L_1 = Medicago sativa L. - Rangelander (Alfalfa)
L_2 = Astragalus cicer L. - Oxley (Cicer milk-vetch)
L_0 = Grass only

Grasses and legumes were planted in same row and crested wheatgrass was planted between experiment rows to eliminate edge effects

TABLE 3

PLANTING RATES FOR
GRASSES & LEGUMES - Bases on 200 seeds/Meter of Row

	Seeds/lb	Package weight of seed used/6.1 m. Row (g)	% Pure Live Seed
Agropyron trachycaulum	159,000	3.5	86.2
Agropyron smithii	110,000	5	
Agropyron desertorum	175,000	3	
Agropyron dasystachum	154,000	3.5	87.0
Elymus junceus	175,000	3	
Festuca ovina	680,000	1.5	79.0
Calamovilfa longifolia	273,000	3	
Oryzopsis hymenoides	141,000	4	
Medicago sativa	200,000	2	
Astragalus cicer	130,000	4.5 (coated seed)	

TABLE 4

PRECIPITATION AND TEMPERATURE RECORDINGS FOR 1982/83

MONTH	PRECIP. (mm)	TEMP. (^{o}C)			
		Mean Low	Mean High	Low	High
		1982			
JUNE	55.9	6.8	35.05	1	42
JULY	97.79	8.5	25.4	3	33
AUGUST	98.04	7.3	25.4	3	32
SEPTEMBER	6.10	2.6	19.6	-4	30
		1983			
MAY	22.86	3.5	18.5	-8	30
JUNE	1.27	9.3	22.4	3	30

2) Soil Testing Results - Sample Analysis *

A preliminary soil test prior to fertilization (Table 5) illustrates the various values before fertilization occurred. The results of an example soil test are shown in Table (6) for August and October of 1982 and May of 1983. The sample is taken from Plot 2 - replicate two for all three sets of analysis.

The analysis shows the progressive nutrient changes in the top thirty six inches over time.

3) Germination Test

A simple germination test was conducted for all grasses grown on the test site. Ten seeds for each grass were placed inside a water saturated paper towel. These towels were in turn placed inside a plastic bag. The seeds were assessed every day to determine germination success.

4) Vegetation Results

The vegetative results are taken mostly from replicate two and once from replicate one because replicates one and three did not produce satisfactory results. Future sampling will incorporate what results are able to be obtained from replicate one. Replicate three produced no usable results.

Three sets of results are illustrated for grass and legume values. Table (7) indicates the fall 1982 results. Table (8) indicates the spring 1983 results. A twenty five centimeter length was used for each row counted to obtain the percentage estimates. These numbers were an attempt to obtain a stem count or percent emergence for the test grasses grown.

The values shown in Table (9) are a visual estimate of the percentage legume and/or grass occupying each row in a plot. The results are noted for each 6.1 meter length which

---

*Soil test done by Soil and Feed Testing Lab, Alberta Agriculture

TABLE 5

EXAMPLE SOIL ANALYSIS - PRIOR TO FERTILIZING

		Electrical Conductivity (S.M.$^{-1}$)	Available Plant Nutrients (ppm)					Cation Exchange Capacity (meq/100g)						Texture	
Sample	pH		NO_3	NH_4	P	K	T.E.C.	Ca*	Mg	Na	K	Ca	%O.M	%Sand	%Silt	%Clay
0-6"	8.0	0.2	0.5	2.4	4.5	100	6.6	52.4	4.0	0.9	1.2	0.5	1.7	88	8	4
0-12"	8.0	0.2	1.0	2.5	2.0	72	4.9	60.6	1.7	0.3	0.4	2.5	1.1	90	8	2
0-6"	8.0	0.2	0.5	3.7	6.0	143	6.6	37.2	2.7	0.9	0.7	2.3	1.7	82	12	6
6-12"	8.1	0.2	0.5	2.7	6.5	202	5.5	57.4	2.2	0.3	0.5	2.5	1.5	88	10	2

*Free Lime and Ca

TABLE 6

SOIL SAMPLES - EXAMPLE ANALYSIS

Sample	pH	Electrical Conductivity (S.M.$^{-1}$)	Plant Nutrients (ppm)					
			NO_3	NH_4	P	K	S	Na
A THREE MONTHS AFTER FERTILIZATION								
1 0-6"	8.1	0.5	35	9.0	4.5	131	4.4	30
2 6-12"	8.1	0.4	17.5	9.5	2.0	133.5	4.2	40.5
3 12-24"	8.4	0.4	17.5	11.6	0.5	72.0		44.
4 24-36"	8.4	0.3	13.0	7.8	0.5	58		34.5
B FIVE MONTHS AFTER FERTILIZATION								
1 0-6"	8.4	0.5	17	6.5	264.5	655	2.4	60.5
2 6-12"	8.5	0.5	28	0.5	170	76	3.2	76
3 12-24"	8.6	0.4	16.5	0	115.5	17		57
4 24-36"	8.7	0.4	14	0	117.5	55.5		55.5
C ONE YEAR AFTER FERTILIZATION								
1 0-6"	8.1	0.2	4.39	7.99	5	113	1.7	5
2 6-12"	8.1	0.3	3.74	13.0	0	77	1.8	5
3 12-24"	8.3	0.2	3.64	9.91	0	48		5
4 24-36"	8.4	0.2	3.38	5.61	0	54		6

TABLE 7

PERCENT GRASS EMERGENCE FOR OCTOBER 1982*

Test Grass	With Alfalfa	With Cicer Milkvetch	Grass Alone
Agropyron trachycaulum (slender wheatgrass-Revenue)	10.4	12.8	12.8
Elymus junceus (Russian wildrye-swift)	9.6	10.8	10.8
Oryzopsis hymenoides (Indian ricegrass)	3.6	2.8	8.8
Agropyron dasystachum (Northern wheatgrass-Elbee)	13.6	18.0	30.4
Agropyron cristatum (Crested wheatgrass-Fairway)	26.0	8.8	16.4
Agropryon desertorum (Crested wheatgrass-Nordan)	11.2	20.0	11.2
Agropyron smithii (Western wheatgrass-Rosana)	7.2	16.8	10.4
Festuca ovina (Sheep fescue-Durar)	8.0	7.6	3.6

*Stem count taken from a 25cm. length and percentages based on 50 planted seedlings per 25cm. length

TABLE 8

PERCENT GRASS EMERGENCE FOR MAY 1983*

Test Grass	With Alfalfa	With Cicer Milkvetch	Grass Alone
Agropyron trachycaulum (slender wheatgrass-Revenue)	22.8	23.6	20.4
Elymus junceus (Russian wildrye-swift)	7.2	13.2	4.8
Oryzopsis hymenoides (Indian ricegrass)	0.8	1.2	5.2
Agropyron dasystachum (Northern wheatgrass-Elbee)	10.8	11.6	13.6
Agropyron cristatum (Crested wheatgrass-Fairway)	24.0	3.6	16.4
Agropyron desertorum (Crested wheatgrass-Nordan)	18.4	8.4	21.6
Agropyron smithii (Western wheatgrass-Rosana)	13.6	8.0	7.6
Festuca ovina (Sheep fescue-Durar)	7.2	12.4	6.0

*Stem count taken from a 25cm. length and percentages based on 50 planted seedlings per 25cm. length.

TABLE 9

A VISUAL PERCENTAGE(*) ESTIMATE OF GRASS AND LEGUME GROWTH (TAKEN FROM REPS ONE AND TWO)

Test Grass	Alfalfa/Grass	Cicer Milkvetch/Grass	Grass Alone
Agropyron trachycaulum (slender wheatgrass-Revenue)	65/5	30/35	25
Elymus junceus (Russian wildrye-swift)	55/1	20/10	-
Oryzopsis hymenoides (Indian ricegrass)	65/0	45/0	-
Agropyron dasystachum (Northern wheatgrass-Elbee)	80/5	15/2	-
Agropyron cristatum (Crested wheatgrass-Fairway)	70/10	15/35	-
Agropyron desertorum (Crested wheatgrass-Nordan)	70/5	7/5	25
Agropyron smithii (Western wheatgrass-Rosana)	60/0	1/0	-
Festuca ovina (Sheep fescue-Durar)	80/0	60/10	-

*Number given represents percentage estimate the particular component occupies of each 6.1 meter row section.

represents the row measurement of alfalfa, cicer milkvetch and grass planted seeded respectively for each replicate. These last results were obtained the first week in July, 1983. Plots that are not shown are those plots for which no data was available or collected.

V DISCUSSION

a) Soil Results

The nutrient status indicates a downward movement of nitrogen. A large amount of nitrate and ammonium has accumulated or become available three months after fertilization. Nitrate accumulates further five months after fertilization. Such accumulation may be due to ammonium-nitrogen changing to nitrate-nitrogen and to a concentration of the surface applied nitrate being held just above the gravel lens level. Ammonium change to nitrate however would be dependent on an active soil micro-organism community (Nitrosomonas and Nitrobacter) which would likely be low in a sandy soil. The increased ammonium levels one year after fertilization is likely due to slow release sulphur coated urea. Potassium and Na rates are likely to fluctuate up and down as somewhat indicated because of the low anion levels and almost non-existent clay component which would bind these elements. The coarse soil texture would allow free water flow up and down as governed by evaporation and rainfall influences and thus allow free cation movement. After one year the nitrates seemed to have leached out and the ammonium is still showing a strong presence again probably because of a slow ammonium release through the sulphur coated urea.

b) Vegetation Results

Because no discernable growth difference occurred between the grasses relative to the type of fertilizer applied, the results for each test grass plot (containing 5 rows per plot) were lumped together.

1) Fall 1982

All grass species showed emergence by October, 1982. For grasses grown with alfalfa, fairway crested wheatgrass showed the highest success. Northern wheatgrass showed the next most promising results. Indian ricegrass showed the least success of the grasses grown with alfalfa.

For grasses grown with cicer milkvetch, nordan crested wheatgrass grew best followed closely by northern wheatgrass. Indian ricegrass also showed the poorest results with the vetch.

The grasses grown without a legume showed northern wheatgrass to have much better emergence than the other grasses. Hard fescue grew the least for the grasses grown without a legume.

For fall emergence the two crested wheatgrass varieties thus seem to compete best with the hardy growing alfalfa. The less persistent vetch showed a slightly changed grass growth response by allowing northern wheatgrass to have a higher emergence probably because of the reduced legume competition. Northern wheatgrass growing alone seems to be an appropriate species for good fall emergence.

2) Spring 1983

All species showed some spring emergence.

Grasses grown with alfalfa showed fairway crested wheatgrass, slender wheatgrass and nordan crested wheatgrass respectively to be the most successful. Indian ricegrass showed virtually no emergence.

Grass response with cicer milkvetch showed slender wheatgrass to have the best emergence. Indian ricegrass emerged the least.

Grasses grown alone showed similar results to grasses grown with alfalfa. Nordan crested wheatgrass, slender wheatgrass and fairway crested wheatgrass respectively were the most successful species. Russian wildrye was the least successful grass for spring emergence.

The two crested wheatgrass varieties and slender wheatgrass are fast germinators and are known to have good persistence. Thus results shown for grass growth with alfalfa and grass growth alone are somewhat expected. Increased russian wildrye and hard fescue growth with cicer milkvetch over that with alfalfa seemed to be a result of shading by the vetch and possibly reduced moisture uptake by the vetch compared to alfalfa. Poor crested wheatgrass growth with the vetch was not expected.

3) Early Summer Results - July, 1983

For grasses grown with alfalfa, the legume completely dominated the plots. From the time alfalfa first germinated in 1982, the legume showed excellent emergence and growth endurance throughout the growing season despite deer and rabbit browsing. Alfalfa has a high water demand and thus, along with the high soil surface temperatures which would reduce available water for newly emerging seedlings, moisture for continual grass growth would be limited. Fairway crested wheatgrass proved the most successful competitor with alfalfa.

Cicer milkvetch showed a better grass/legume growth relationship. Fairway crested wheatgrass and slender wheatgrass illustrated good growth with the vetch. Hard fescue and russian wildrye also showed better growth. Western wheatgrass and indian ricegrass were not evident with the vetch. Grass growth along showed only slender wheatgrass and nordan crested wheatgrass.

Natural vegetation growth and invasion specifically wild rose, sandreed grass, blue grama and more minor amounts of other native species provided increasing competition for the vetch and grasses growing on the plot. Alfalfa competed very well with the native vegetation. The native species especially sandreed grass (Calamovilfa longifolia) were more pronounced on the test site than the surrounding area. Such enhanced growth was quite certainly a fertilizer response. The legumes did not show any evidence of healty or abundant nodulation. The higher fertilizer applications probably inhibited nodulation activity.

4) Germination Test

All species germinated 100% within five days except western wheatgrass which germinated 90%. Western wheatgrass stayed at 90% germination.

CONCLUSIONS

The above results indicate that grasses should be seeded separately from alfalfa to compete successfully with this legume. An alternate row spacing of grass cross seeding at ninety degrees to alfalfa would probably produce more successful grass growth.

Grass seeding with cicer milkvetch produced more acceptable results even though the vetch showed less successful growth than alfalfa. The grasses grew more successfully with the vetch probably because of reduced legume competition. Cicer milkvetch is thus seen to be a viable legume to plant directly with grasses in a coarse textured soil in an arid climate.

To overcome feathery seeds and thus drill seeding problems, seeds such as sandreed grass and little blue stem would have to be coated to allow passage through a drill seeder.

ACKNOWLEDGEMENT

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RECLAMATION AND EROSION CONTROL CONCERNS OF ONTARIO HYDRO

W.E. WELCH
Environmental Resources Section
Transmission Environment Department
Ontario Hydro
Toronto, Ontario

ABSTRACT

Through the construction and operation of its facilities, Ontario Hydro becomes involved in some specialized reclamation and erosion control projects. This paper will briefly present three examples of projects conducted more recently.

The first project concerns the reclamation of a large spoils pile which resulted from excavation at the site of the Darlington Nuclear Generating Station east of Toronto. The excavated material was composed of silty sand and glacial till. Because of the size of the pile, the cost of using topsoil was determined to be prohibitive. A testing program was instituted to examine/test seed mixtures, application methods and binders best suited for reclaiming the pile. It was decided that 4 different mixtures would be used as determined by slope, drainage, exposure and visibility.

The second project involves coal fired generating stations and fly ash which is disposed of differently at each station (on-site disposal or trucked away). A subject of concern has been the reclamation of these disposal areas with vegetation to prevent wind erosion and transport of ash off site. A greenhouse pot experiment was conducted to screen grass and legume species on different ashes. The results pointed to wheatgrasses, tall fescue and perennial rye as being best suited for these harsh conditions. Additions to the ash greatly improved success.

The last project described deals with secondary land use which often causes erosion problems on high voltage rights-of-way. One such example was the result of changing drainage patterns through subdivision construction. A temporary gabion mat, sand bag method was initially used to control the flow of water down the right-of-way, however, the problem became worse. The final solution involved using rock riprap, hydroseeding, sodding, and significant regrading to correct the problem.

INTRODUCTION

Through the construction and operation of its facilities, Ontario Hydro becomes involved in some specialized reclamation and erosion control projects. These projects are over and above the normal restoration process which takes place following the construction of a transmission line right-of-way. Projects have included river and headpond bank stabilization, spoils pile reclamation, abandoned gravel pit rehabilitation, coal fly ash reclamation, and erosion problems caused by secondary land use of our rights-of-way. These projects have involved several departments within Ontario Hydro. This paper is intended to provide a brief overview of three such projects conducted recently; spoils pile reclamation, coal fly ash reclamation and an example of a secondary land use erosion problem.

Spoils Pile Reclamation

Excavations for Ontario Hydro's Darlington Nuclear Generating Station, which is situated on the north shore of Lake Ontario near the Town of Newcastle 60 km east of Toronto, resulted in a large spoils pile with an approximate area of 37 ha. The spoils material consisted of glacial till, lacustrine deposits, and interglacial sands, silts and clays. For disposal purposes, the pile was divided into two sections (see Figure 1); the south portion for stockpiling the upper till and lacustrine material and the northern portion for disposing of the interglacial material. Initially, the high erodability of the interglacial material presented some difficulty, particularly through the freeze-thaw process. As a result, it was decided to cap the interglacial material with till material which was less impervious to water and, therefore would reduce the probability of recharge by precipitation.

Before specifications for the vegetative reclamation of the pile could be identified, a testing program was undertaken to determine the best selection of application methods, seed mixes and mulch/binder options. This was done for the following reasons:

1. The area to be treated was significantly large, therefore, it was very important to determine the best method at the least cost.

2. The spoils material provided difficult growing conditions for establishment and growth because:

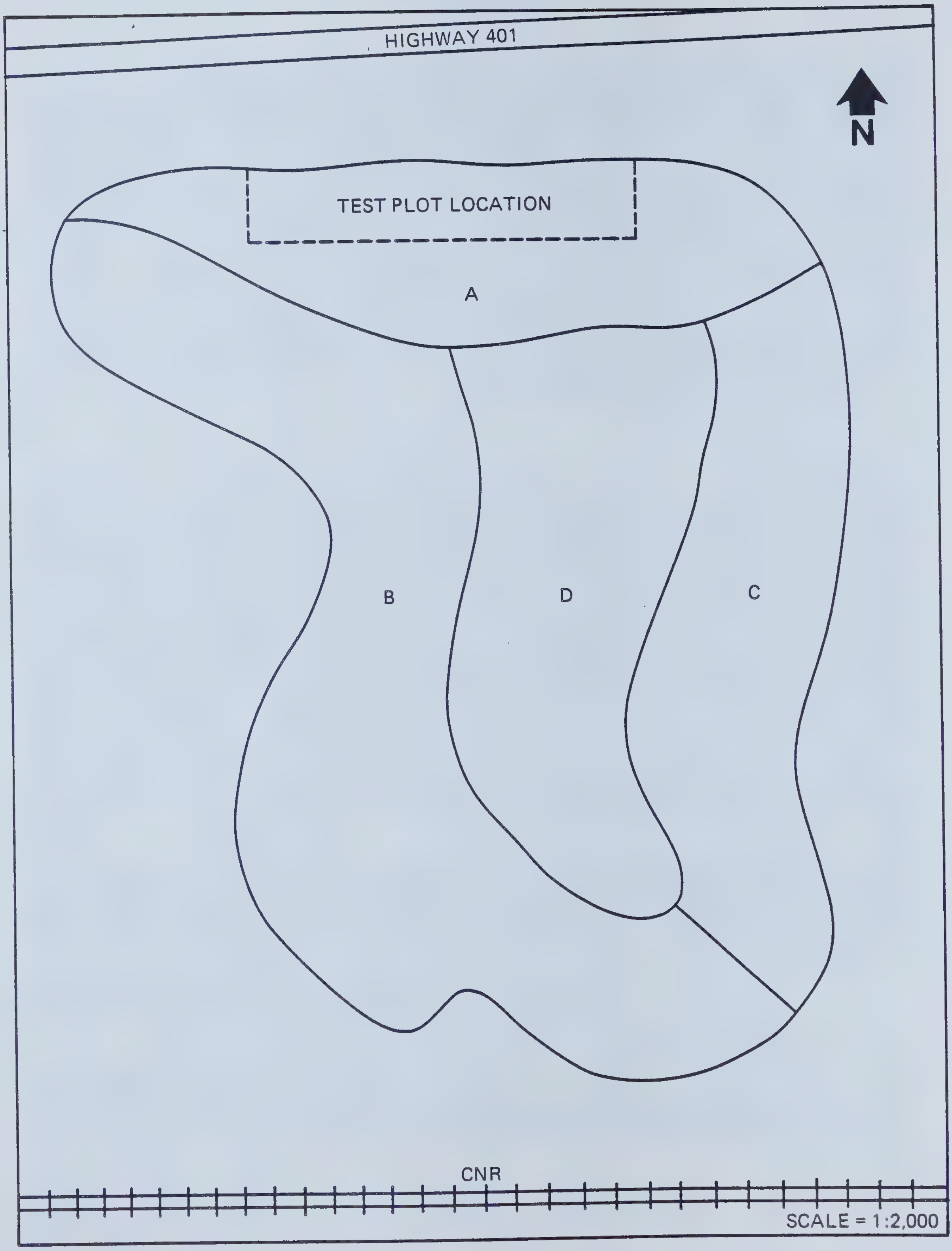
HIGHWAY 401
N
TEST PLOT LOCATION
A
B
D
C
CNR
SCALE = 1:2,000

Figure 1 Diagram of the spoils pile at Darlington Nuclear Generating Station illustrating the location of the test plots and the four different final treatment areas.

   (a) Soils consisted of fine sand with some silts which were extremely susceptible to wind and water erosion.

   (b) No organic matter was present and no topsoil was used to cap the pile.

   (c) The site was exposed to full sunlight and harsh winds.

3. Ontario Hydro's experience in reclaiming such sites was limited.

4. The general body of knowledge relating to vegetating such sites was somewhat limited.

5. The area was highly visible from a major highway so it was important to determine a method that ensured a thick, lush cover.

In June 1979, a set of experimental plots was established in an 8 000 m^2 area on the north slope of the spoils pile. Figure 2 illustrates that this area was divided into eight 900 m^2 plots. The area surrounding the plots on the east and south sides was reserved for seeding of a nurse crop. Table 1 lists the treatment options chosen for each of the plots; it was decided to test three different seed mixtures, three different application methods and two mulch/binder applications.

Seeding of the plots took place June 26 to 29, 1979 using the treatments listed in Table 1 and the following equipment:

Hydroseeding - Reinco HG-15 Hydrograsser

Discing - Gill scarifier

Seed drill - Brillion seeder

Broadcasting seed and fertilizer - Cyclone seeder

Weather conditions after the seeding was completed were far from ideal (hot and dry); however, the results did provide an indication of the best method of application, seed mix, and mulch material. Table 2 presents a ranking of the treatment methods; method 7 performed the best. The application method which showed the best results with seeding was the Brillion seeder, particularly during

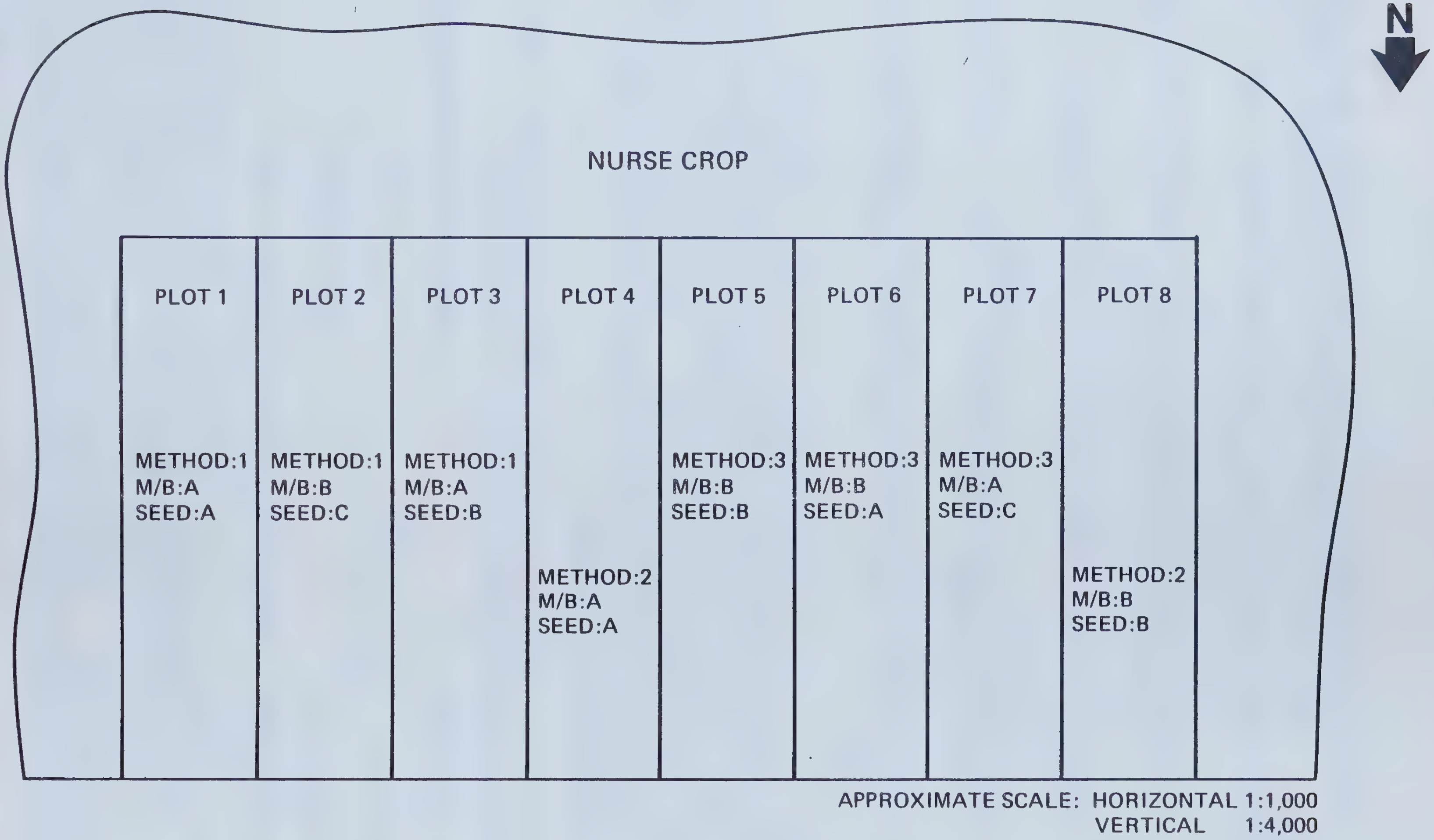
N
NURSE CROP
PLOT 1
METHOD:1
M/B:A
SEED:A
PLOT 2
METHOD:1
M/B:B
SEED:C
PLOT 3
METHOD:1
M/B:A
SEED:B
PLOT 4
METHOD:2
M/B:A
SEED:A
PLOT 5
METHOD:3
M/B:B
SEED:B
PLOT 6
METHOD:3
M/B:B
SEED:A
PLOT 7
METHOD:3
M/B:A
SEED:C
PLOT 8
METHOD:2
M/B:B
SEED:B
APPROXIMATE SCALE: HORIZONTAL 1:1,000
VERTICAL 1:4,000

Figure 2 Detail of the eight test plots showing the treatment methods used for each. The application methods, mulch/binder options and seed mixtures are described in Table 1.

Table 1 Application methods, mulch and binder options, and seed mixtures used on the test plots at Darlington Nuclear Generating Station site.

Applications Methods

Method 1

Applied together by hydraulic seeder:

- Mulch at 1 600 kg/ha
- Binder
- Seed plus innoculant (specified below)
- Nurse crop
- Fertilizer
- Water @ 30 000 L/ha

Method 2

Materials applied by hydraulic seeder in two steps:

Step 1:

- Mulch @ 600 kg/ha
- Seed plus innoculant
- Nurse crop
- Fertilizer
- Water @ 10 000 L/ha

Step 2:

- Mulch @ 1 000 kg/ha
- Binder
- Water @ 20 000 L/ha

Method 3

Materials applied in three steps as follows:

Step 1:

Broadcast 50 percent of total fertilizer requirements (i.e., 5-20-20 @ 250 kg/ha plus SCU @ 65 kg/ha), followed by discing the area to a depth of 5 cm.

Table 1 (cont'd)

Step 2:

Innoculated seed applied using a Brillion or similar seed drill, to a depth of approximately 1 cm.

Step 3:

The following applied by hydraulic seeder:

- Mulch @ 1 600 kg/ha
- Binder
- Nurse crop
- Remaining required fertilizer
- Water @ 30 000 L/ha

Mulch Plus Binder

Mulch/Binder "A"

The hydromulch was a natural wood fibre produced from clear, whole wood chips, containing no growth or germination inhibiting substances and dyed to facilitate visual metering during application (Conwed hydromulch).

The binder was Curasol AH applied at a rate of 224 kg/ha.

Mulch/Binder "B"

The hydromulch consisted of natural sun-dried plant fibres and processed in lengths of 2 to 4 cm, (Verdyol mulch).

The binder was Verdyol Super applied at a rate of 100 kg/ha.

Seed Mixtures

Mixture "A"

- Crown vetch @ 22 kg/ha
- Creeping red rescue @ 62 kg/ha
- Crown vetch innoculant @ 0.85 kg/ha

Table 1 (cont'd)

Mixture "B"

- Birdsfoot trefoil @ 22 kg/ha
- Creeping red fescue @ 62 kg/ha
- Birdsfoot trefoil innoculant @ 0.85 kg/ha

Mixture "C"

- Creeping red fescue @ 45 kg/ha
- Kentucky blue grass @ 20 kg/ha
- Redtop @ 4 kg/ha
- White dutch clover @ 3 kg/ha

Nurse Crop

The nurse crop was Italian ryegrass (Lolium multiflorum) and which was seeded at the following rates:

Treatment plots (ie, along with other seed mixtures, above), @ 17 kg/ha

Buffer strips (no other seed), @ 30 kg/ha

Fertilizer

The total application rate for all areas was:

5-20-20 at 500 kg/ha, plus
Sulfur coated urea (SCU) at 130 kg/ha

Buffer Areas

The areas immediately to the south and to the east of the treatment plots were seeded with nurse crop only, as follows:

- Nurse crop @ 30 kg/ha
- Fertilizer
- Mulch plus binder - either "A" or "B" above

Table 2 Results of test plots based on grass stem counts taken in August 1980; ranked in order greatest to least success.

Plot	Treatment*
7	3Ac
6	3Ba
5	3Bb
4	2Aa
1	1Aa
3	1Ab
2	1Bc
8	2Bb

*where 1, 2, 3 = application type; A = Conwed/Curasol, B = Verdyol; a = crown vetch - creeping red fescue, b = birdsfoot trefoil - creeping red fescue, c = creeping red fescue - kentucky bluegrass - redtop - whitedutch clover ("MTC" mix).

the hot summer months. The best mulch/binder combination was the Conwed-Curasol option while the best seed mixture was found to be the "MTC" mix (Mix C). With these results, it was possible to specify a treatment for the entire spoils pile.

On close examination of the pile, it was decided that there were four areas requiring different seed mixtures for the following reasons:

1. Problems of slope and drainage

2. Exposure

3. Visibility

Table 3 presents the four different seed mixes, application rates and methods of application used on Areas A, B, C and D shown in Figure 1. In all cases the seed was drilled into the soil using a Brillion seeder followed by hydroseeding and mulching; seeding of the pile was completed in early June 1980. Any areas where there were severe drainage problems (channelling or gulleying) were protected using rock riprap material.

Another aspect of the contract was the planting of 1845 trees and shrubs with particular emphasis along the north edge of the spoils pile adjacent to Highway 401 (see Figure 1). This planting was done primarily to help reduce the visual impact of the spoils pile and to tie in with existing vegetation on the site.

In general, the seeding program was a success with a reasonable cover establishing in the first season. A maintenance fertilization was conducted in 1981 and the cover is continuing to develop.

Coal Fly Ash Reclamation

The problem of disposing of coal fly ash which is removed from electrostatic precipitators during the burning of coal at thermal generating stations is significant and world-wide. Ontario Hydro presently employs three methods for disposal of fly ash at its generating stations.

1. Dry disposal land fill in an abandoned quarry.

2. Disposal into on-site containment cells.

Table 3 Seed mixtures, application methods and rates used on the final treatments of the Darlington spoils pile. Areas indicated relate to those shown in Figure 1.

Grass Seed Mixtures

Seed Mixture "A": "North Slope"

MR-77 Roadside Mixture	90%
White Dutch Clover (*Trifolium repens*)	10%

Mechanically seed at 100 kg/ha, and hydroseed at 50 kg/ha.

Seed Mixture "B": "West-South Slope"

Crown Vetch (*Coronilla varia*)

Mechanically seed at 22 kg/ha,

plus

Creeping Red Fescue (*Festuca rubra*)	85%
Perennial Ryegrass (*Lolium perenne*)	15%

Mechanically seed at 40 kg/ha and hydroseed at 20 kg/ha.

Seed Mixture "C": "East Slope"

Creeping Red Fescue	45%
Kentucky Bluegrass (*Poa pratensis*)	20%
Smooth Brome (*Bromus inermis*) (clipped seed)	15%
Perennial Ryegrass	10%
White Dutch Clover	10%

Mechanically seed at 54 kg/ha, and hydroseed at 27 kg/ha.

Seed Mixture "D": "Top of Spoil Pile"

Birdsfoot Trefoil (*Lotus corniculatus*)

Mechanically seed at 10 kg/ha.

Table 3 (cont'd)

Canada Bluegrass (*Poa compressa*)	55%
Sheep's Fescue (*Festuca ovina*)	35%

or

Hard Fescue (*Festuca ovina* var *Duriuscula*)	
Redtop (*Agrostis alba*)	5%
Perennial Ryegrass	5%

Mechanically seed at 40 kg/ha, and hydroseed at 20 kg/ha.

Seeding Operation

The seeding operation was carried out between May 1 and June 15, 1980.

Immediately prior to mechanical seeding, fertilizer (below) was broadcast uniformly using a cylone seeder.

Seeding was done in two stages. First all of the legume seed (crown vetch or birdsfoot trefoil) and two-thirds of the grass seed mixture was mechanically seeded (Brillion seeder) and second, the remainder one-third of the grass seed mixture was incorporated into the hydraulic mulch. Hydromulching followed the mechanical seeding on the same day.

Fertilizer

Analysis: 5-20-20 applied at a rate of 500 kg/ha, *plus* Sulphur-coated urea (32-0-0) at 110 kg/ha.

3. Disposal of ash in a slurry which forms a delta in an on-site settling pond or lagoon.

The disposal of fly ash in an abandoned quarry does not necessarily require reclamation until the site has at least been partially completed (progressive reclamation). The on-site disposal systems have some immediate problems, the most significant of which is blowing fly ash transported off-site from the disposal area. Several options have been considered as a solution to this problem, two of which were a temporary but relatively expensive measure of spreading a dust suppressant material over the ash surface or developing a permanent vegetation cover on the ash. Due to high costs, however, Ontario Hydro decided not to cap the ash with topsoil severely restricting the potential success of a vegetation cover. In 1980, the Transmission Environment Department was requested to provide specifications for vegetative treatment of the ash lagoon delta at Nanticoke Thermal Generating Station (TGS) on the north shore of Lake Erie. It was suggested that the following seed mixture be drilled into the ash at a rate of 40 kg/ha:

45 percent perennial rye
40 percent creeping red fescue
15 percent white sweet clover

The fertilizer recommended for this seeding was 10-20-20 applied at a rate of 500 kg/ha. This attempt was almost a total failure due primarily to differing qualities of ash in the delta (age of deposition, course bottom ash to fine fly ash), high pH and high boron content and other chemical elements, as well as a hot dry summer. As a result of this failure, Transmission Environment was requested to conduct a greenhouse research project to determine the best species and ash treatments in order to establish a vegetation cover on the ash delta at Nanticoke TGS, the ash delta at J.C. Keith TGS in Windsor and the ash disposal cells at Thunder Bay TGS in Thunder Bay.

The work was conducted in two phases; Phase One considered only Nanticoke ash samples taken from the disposal delta and Phase Two considered precipitator (unweathered) ash samples from all three of the above stations. For both phases, the experimental regime was similar; a greenhouse pot experiment testing different species of grasses and legumes and additions to the ash.

In Phase One, 20 species of grasses and legumes and two ash treatments were tested (see Table 4) on four different qualities of ash. All pots were fertilized using 13-44-44 fertilizer at a rate of 400 kg/ha before seeding with 20 seeds of each species. The

Table 4 Ash, ash treatments and species used in the Phase One greenhouse trials (Nanticoke ash only).

Ash*	Amendments	Species
1. Bottom ash	1. Subsoil	Crested wheatgrass
		Tall wheatgrass
2. Bottom ash plus some fly ash	2. Undigested sewage sludge	Streambank wheatgrass
		Violet wheatgrass
		Pubescent wheatgrass
3. Older fly ash		Western wheatgrass
		Russian wild ryegrass
4. Recently deposited fly ash		Tall fescue
		Orchard grass
		Canada bluegrass
		Rough bluegrass
		Perennial ryegrass
		Alkaki grass
		Alfalfa
		Cicer Milkvetch
		Yellow blossom sweet clover
		White blossom sweet clover
		Alsike clover
		Barley
		Oats

*Coal burned was a mixture of American and Western Canada coal. The four samples were taken from different locations on the delta.

pots were monitored over a four-month growth period by taking weekly stem counts. At the end of this growth period, all the plants were harvested for dry weight analysis. Based on three measures of success (apparent germination, survivorship, and above-ground biomass), the 20 species were given a ranking (see Table 5). This ranking was used to develop specifications for seeding of the Nanticoke TGS fly ash delta (Ontario Hydro, 1982).

During Phase Two, precipitator ash was obtained from the three stations. Due to the harsh (primarily chemical) nature of dry fly ash, it was necessary to weather (leach) the ash for a three-month period before seeding. Table 6 presents the ash and treatment options used in this phase. The species used in Phase Two consisted of the 10 best species from Phase One (see Table 6). Once seeded, the pots were monitored over a three-month period after which all plants were harvested for dry weight analysis; as was done in Phase One. The measures of success used in Phase One were used in this phase to rank the species and treatments according to station (see Table 7). These rankings were then used to develop specifications for treatment of ash at each station (Ontario Hydro, 1983).

In all cases, it was found that the best success was obtained when material was added to the ash, e.g., subsoil, composted sewage sludge or peat. These results are consistent with work conducted by other researchers (e.g., Railton and Lulman, 1982). Tall wheatgrass and tall fescue performed consistently well in these tests. The next logical step in this type of work is in-field testing; a process which is now being considered for one of the stations.

Erosion Due to Secondary Land Use

Ontario Hydro frequently must deal with secondary land use of its property and the problems which are created by such use, one of which is erosion. The example described below was the result of subdivision construction adjacent to one of our high voltage rights-of-way in Oshawa, east of Toronto.

The construction of a subdivision adjacent to our right-of-way necessitated clearing and regrading of Ontario Hydro property. Figure 3 illustrates the site indicating the location of the subdivision with respect to the right-of-way. The natural flow of water was originally across the corridor in an east-west direction. In regrading the right-of-way, a shallow drainage channel was dug along the western edge to accommodate surface and

Table 5 Ranking of the 20 species based on their success on the Nanticoke ash; listed in order of greatest to least success.

- Tall wheatgrass
- Tall fescue
- Perennial ryegrass
- Pubescent wheatgrass
- Streambank wheatgrass
- Oats
- Alkali grass
- Barley
- White blossom sweet clover
- Russian wild ryegrass
- Alsike clover
- Alfalfa
- Violet wheatgrass
- Crested wheatgrass
- Orchard grass
- Western wheatgrass
- Yellow blossom sweet clover
- Rough bluegrass
- Canada bluegrass
- Cicer milkvetch

Table 6 Ash, ash treatments and species used in the Phase Two greenhouse trials.

Ash	Amendments	Species*
Thunder Bay		
1. Bottom ash from Saskatchewan lignite coal	Peat Sewage sludge Lignosulfonate liquor	Tall wheatgrass Streambank wheatgrass Pubescent wheatgrass Oats Russian wild rye Tall fescue Orchard grass Perennial ryegrass White blossom sweet clover Alsike clover
2. Fly ash from 2.3 percent US bituminous coal		
3. Fly ash from Saskatchewan lignite coal		
J.C. Keith		
Fly ash from 1.7 percent sulphur coal	composted sewage sludge cake	
Nanticoke		
Mixture of U.S. and Western Canadian bituminous coal	subsoil	

*Note: The same species were used for all three stations.

Table 7 Overall ranking of the species for each station based on success in the greenhouse trials; listed in order of greatest to least success.

Thunder Bay	J.C. Keith	Nanticoke
Tall wheatgrass	Tall wheatgrass	Streambank wheatgrass
Tall fescue	Oats	Tall fescue
Pubescent wheatgrass	Russian wild rye	Pubescent wheatgrass
Oats	Pubescent wheatgrass	Tall wheatgrass
Streambank wheatgrass	Streambank wheatgrass	Perennial Ryegrass
Orchard grass	Perennial ryegrass	Russian wild rye
Perennial ryegrass	White blossom sweet clover	Orchard grass
Russian wild rye	Tall fescue	Oats
Alsike clover	Alsike clover	Alsike clover
White blossom sweet clover	Orchard grass	White blossom sweet clover

subsurface flows southward to a municipal storm sewer. The soils at the site consisted of organic muck at the north end (for 100 m) grading into fine sand in the southern section (for 200 m). When the clearing and regrading work was initially completed no channel protection was provided. The result of no protection was erosion of the channel sides and a high degree of sedimentation at the outfall to the municipal drain. As a temporary measure, the sediment was removed, gabion mats were installed on top of a filter fabric at the outfall and riprap was placed above and below the gabion work (see Figure 3). In order to decrease the flow of water down the channel, sandbag defectors were installed at 20 m intervals for a distance of 100 m up the channel. These were used to help slow the flow of water and cause deposition of some of the sediment before the outfall. Problems developed fairly quickly in that the gabion mats were undercut and the sandbag deflectors were simply diverting the flow to further cut away at the channel banks.

In the following year, it was decided to create a grassed waterway because of the rapid erosion and high sediment load. The grassed waterway was chosen since it would stabilize the banks while at the same time act to reduce the velocity of the water. The work was conducted in several stages:

1. Removal of sandbag deflectors.

2. Grading the banks of the drainage channel to a 3:1 slope.

3. The entire channel and right-of-way was hydroseeded with a mixture of timothy, bromegrass, and redtop.

4. The outfall was regraded to a 4:1 slope for the channel and 3:1 for the banks. The bed was lined with Terrafix fabric followed by 10 to 15 cm of up to 10 cm diameter rock.

5. The area immediately surrounding the outfall was sodded as was the sharp turn in the drainage channel (see Figure 4).

6. A catchment basin was installed at the north end of the right-of-way when it was discovered that a storm sewer passed under the site. The area surrounding the catchment was sodded (see Figure 4).

An excellent cover has established on the site and there are no longer any problems with erosion.

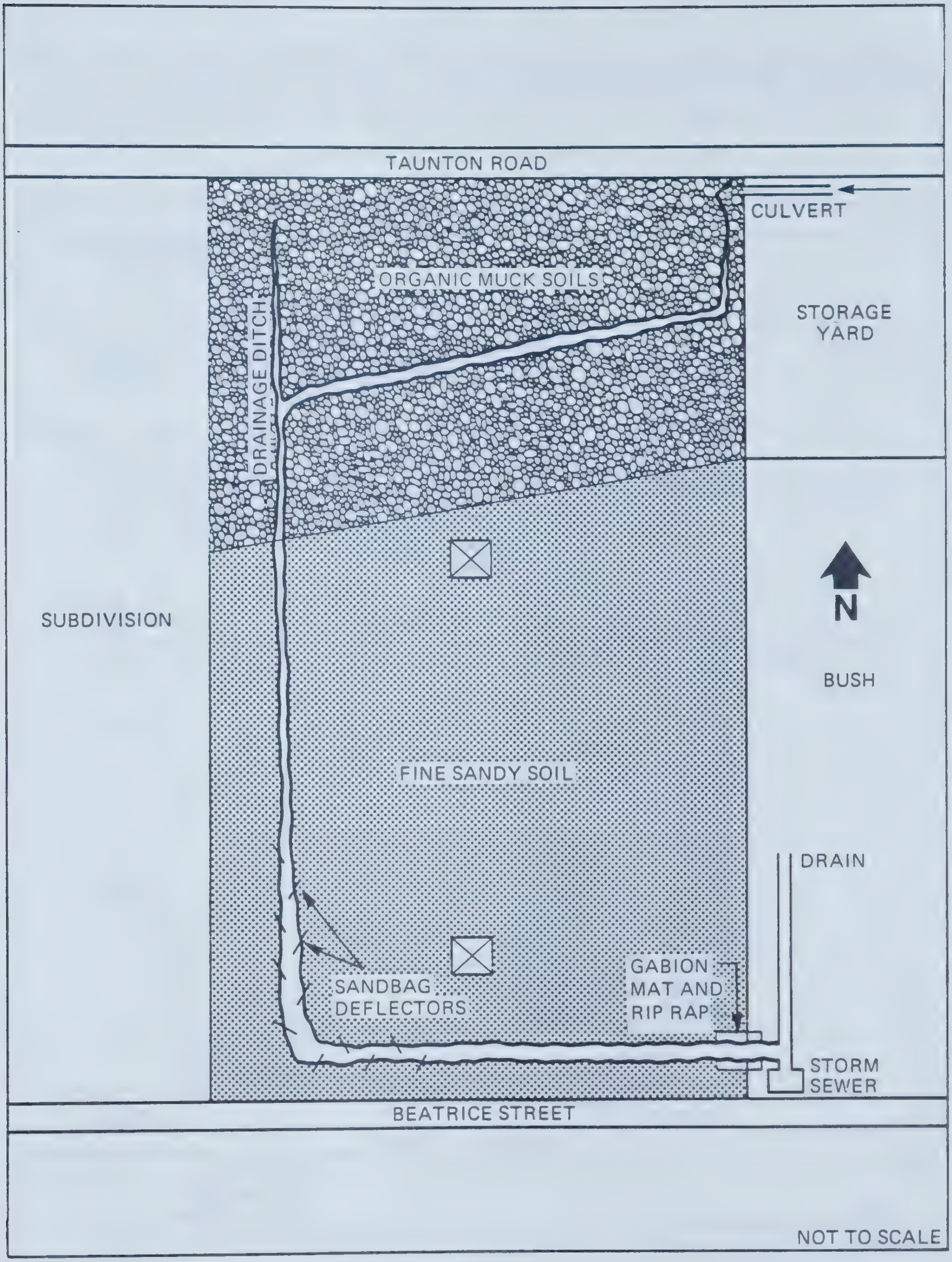
TAUNTON ROAD
CULVERT
ORGANIC MUCK SOILS
DRAINAGE DITCH
STORAGE YARD
SUBDIVISION
N
BUSH
FINE SANDY SOIL
DRAIN
SANDBAG DEFLECTORS
GABION MAT AND RIP RAP
STORM SEWER
BEATRICE STREET
NOT TO SCALE

Figure 3 Illustration of the right-of-way showing the soils and the temporary erosion control measures.

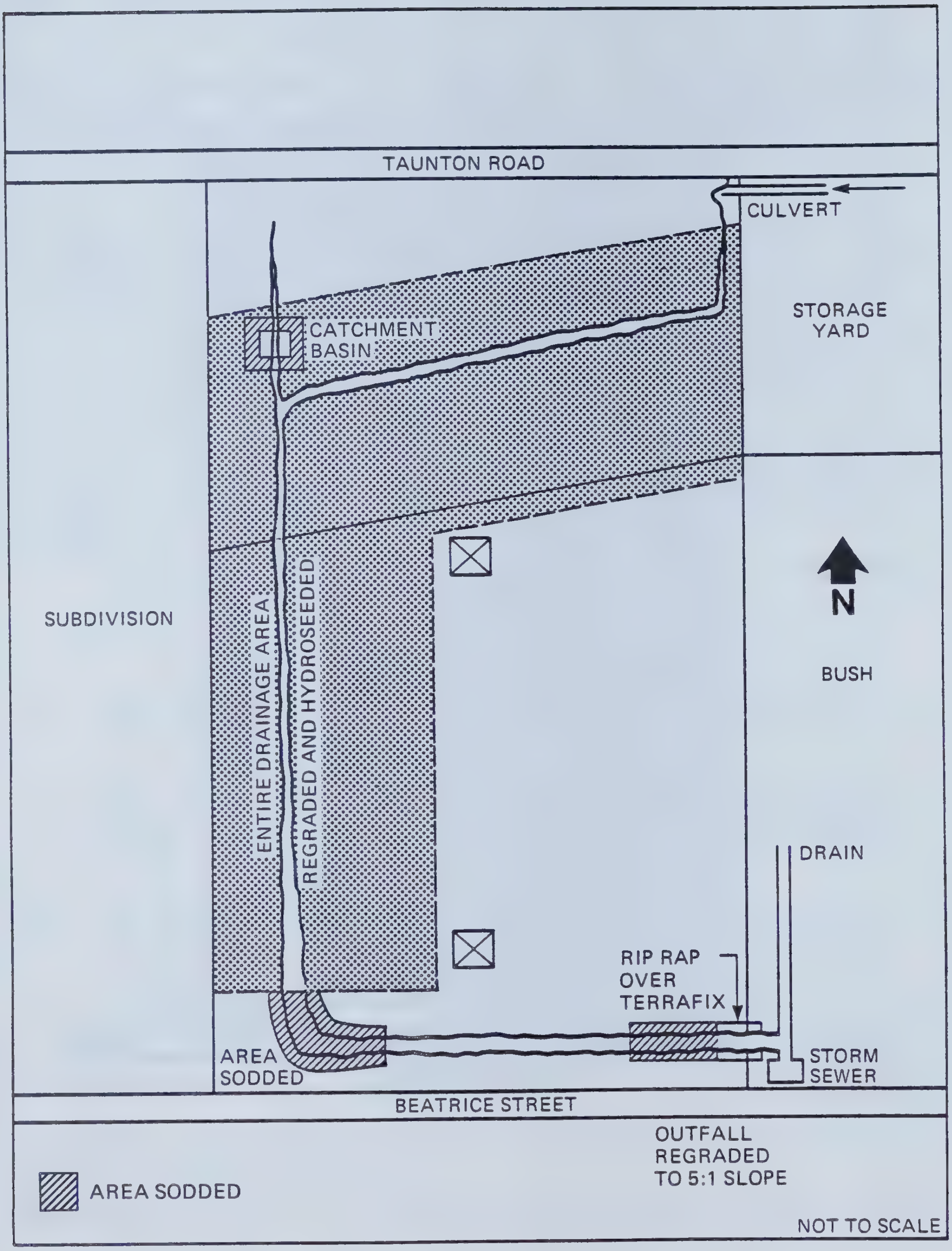
TAUNTON ROAD
CULVERT
STORAGE YARD
CATCHMENT BASIN
SUBDIVISION
ENTIRE DRAINAGE AREA
REGRADED AND HYDROSEEDED
N
BUSH
DRAIN
RIP RAP OVER TERRAFIX
STORM SEWER
AREA SODDED
BEATRICE STREET
OUTFALL REGRADED TO 5:1 SLOPE
AREA SODDED
NOT TO SCALE

Figure 4 Final treatment of the right-of-way following removal of the temporary measures.

While this paper provides only three very abbreviated descriptions of these projects, it does give an indication of the types of problems encountered by Ontario Hydro in the operation of its facilities.

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AGGREGATE MINE REHABILITATION: A PLANNING MODEL

Monica E.S. Gewurz
Landscape Architect
Environmental Planner
Guelph, Ontario

ABSTRACT

There are many types of land dereliction: gravel extraction, metal mining, coal mining, pipeline construction, abandoned industrial areas, among others. Each type calls for one or more rehabilitative techniques to deal with its particular effects. No single model will be able to cope with all the problems that may arise, but a detailed one will be of use in establishing the principles involved and the techniques which are available for rehabilitation.

The purpose of such a model is to give the detailed direction and sequence to the rehabilitation process which allows it to be carried on from the beginning of the mining operation to the final post mining rehabilitated land use.

In response to literature which generally treats the process of aggregate mine rehabilitation in a segmented way despite the considerable body of information which is available this paper develops a holistic approach to the Aggregate Mine Rehabilitation Planning Model (A.M.R.P.M.). This approach integrates techniques and processes from several disciplinary areas (technical, scientific, administrative) to establish a detailed management system from pre-extraction to post-extraction operations and to aid in land-use planning. The AMRPM herein developed will find application in aggregate development projects where objectives are post-extractive conditions and/or preparation of the land for alternative land uses usually associated without urban development. This model is intended to serve as a framework for rehabilitation projects in general.

INTRODUCTION

The Canadian Landscape is undergoing a significant change due to its active aggregate mining industry. This evolving industry offers a great opportunity for the Landscape Architect to get involved in creative reclamation activities such as shaping these lands into new and useful forms. Reclamation of mined lands is becoming a complex activity requiring input fgom various disciplines including landscape architecture, planning, engineering and the physical, biological, managerial and social sciences.

In this presentation I will describe the Aggregate Mine Rehabilitation Planning Model (A.M.R.P.M.) not elsewhere documented, which should assist other landscape architects, operators, researchers and pit-quarry owners to rehabilitate a site progressively.

In this model an attempt has been made to integrate technical, scientific and administrative aspects, to establish a detailed rehabilitation management system from pre-extraction to post-extraction operations, and to aid in mining and site land use planning. The model can be used in aggregate mining projects of any kind, where rehabilitation goals require the site to be rehabilitated to a pre-mine condition and/or to prepare the land for alternative land uses. Over time, as policy changes and other determining factors change, the model may be reviewed and updated without destroying its basic validity. The model is made of 41 steps (see Fig. 1).

Step 1 or Proposed land disturbance

In this stage the owner/operator will describe the amount of land to be disturbed after studies of geologic deposits are made by the company and/or the government.

Step 2 deals with the Licensure to Mine

After applying to government authorities for an approval a permit is granted. An appeal system is in place should a permit be denied.

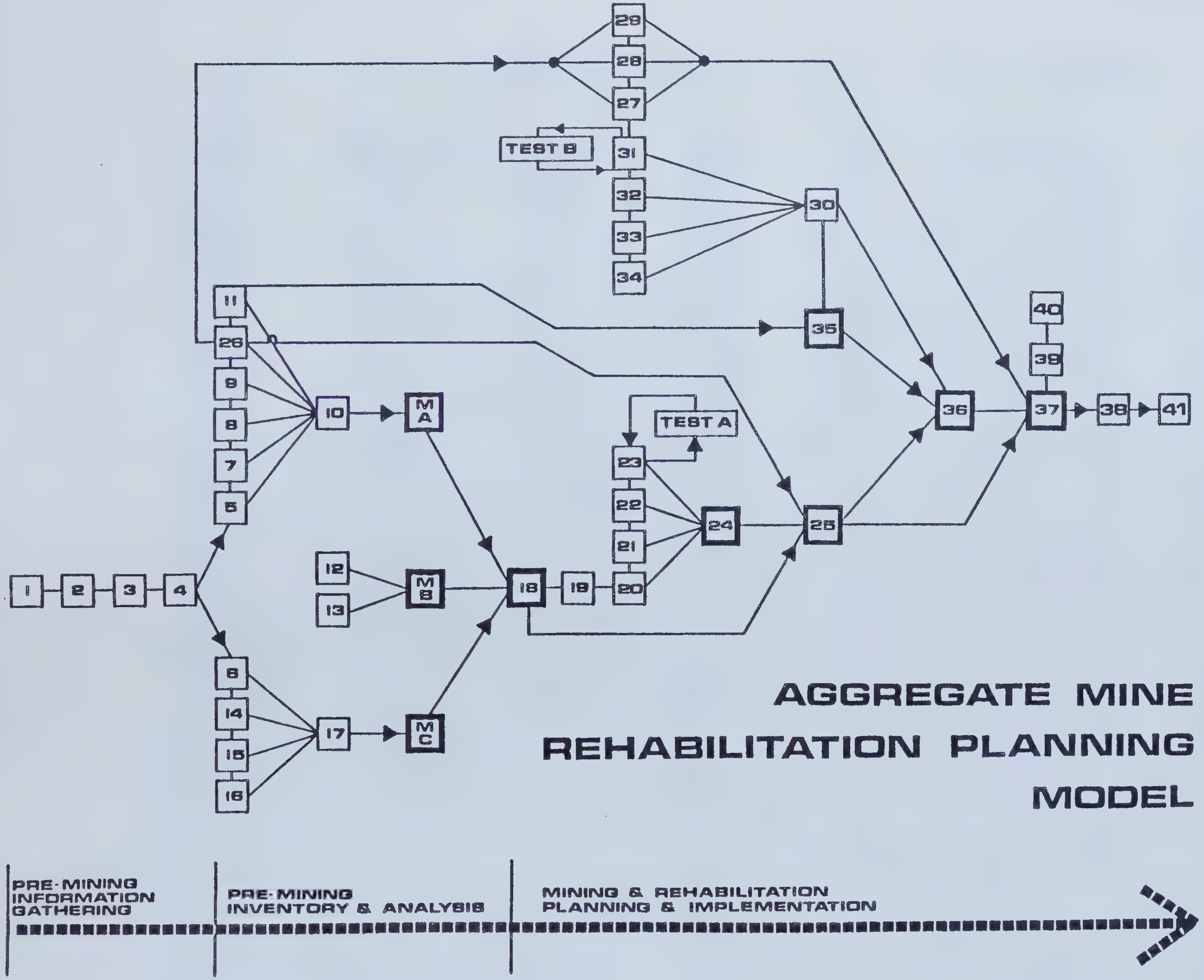
Step 3 or Land Management Objectives

In this step the mining company states what their general objectives are for the progressive rehabilitation sequencing, and what future land use(s) the company assumes the mine site will give rise to.

Step 4 or Policy Development

Land rehabilitation objectives should be in accordance with current government policies. This will provide a framework for

FIGURE 1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TEST A
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TEST B
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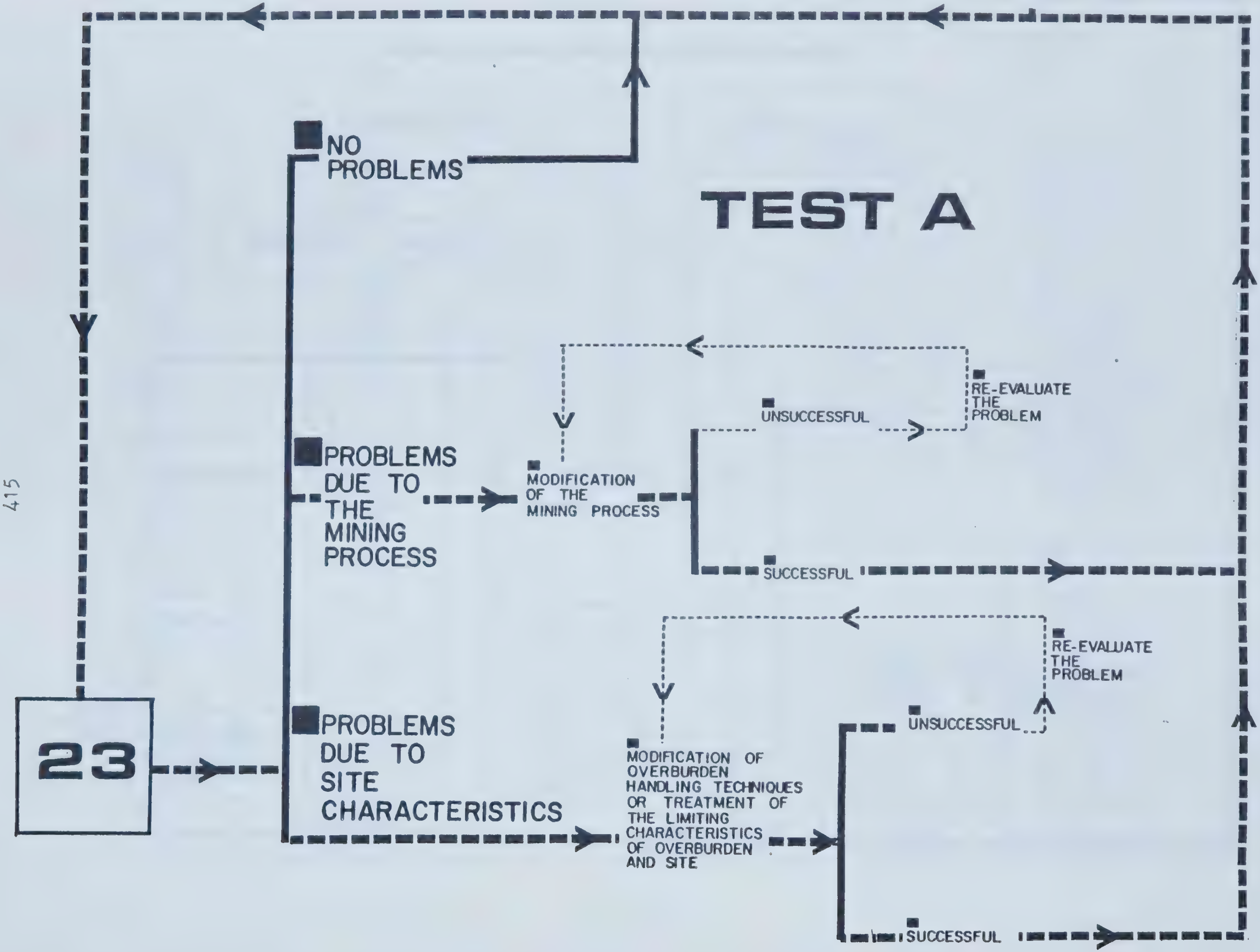
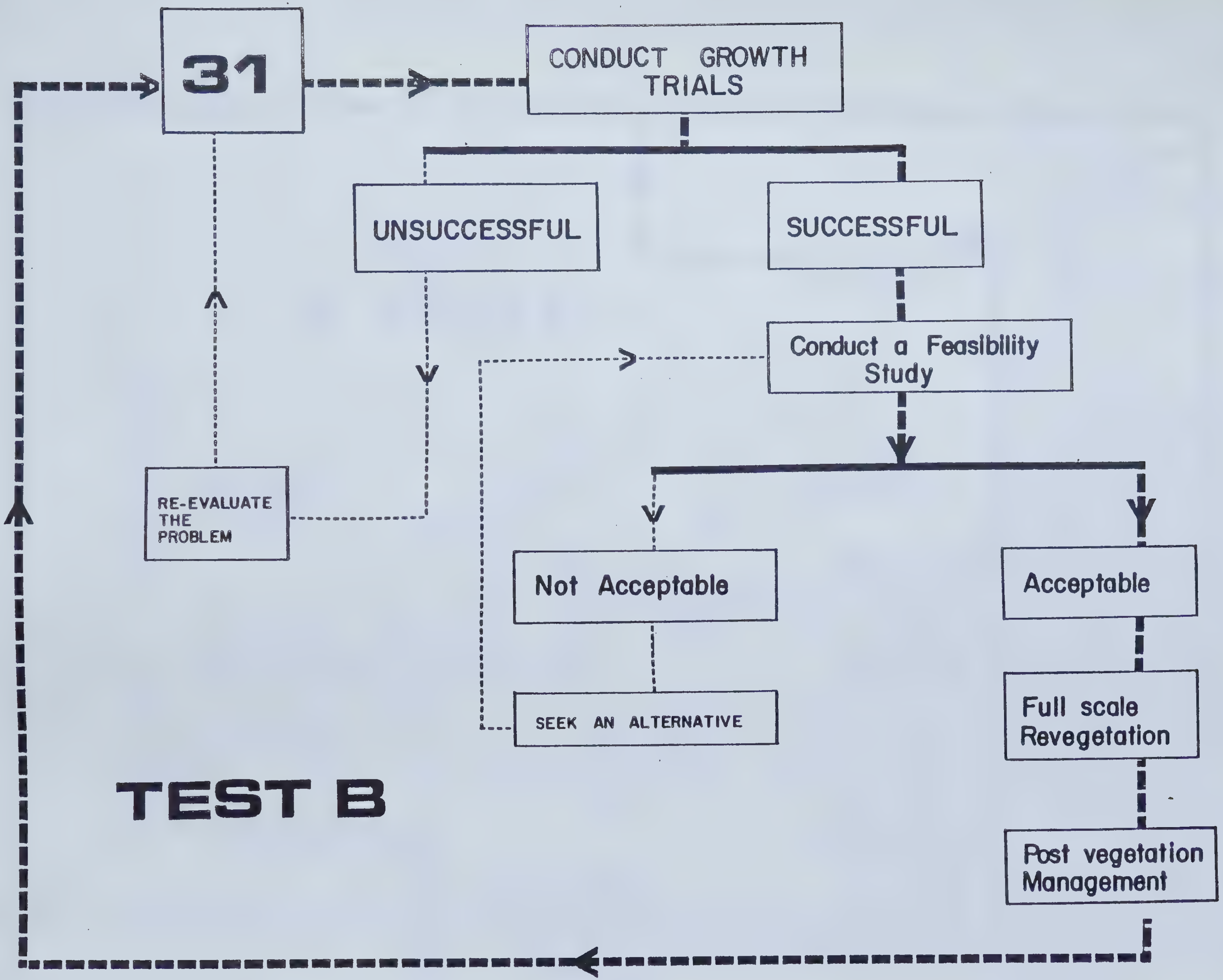
PRE-MINING INFORMATION GATHERING
PRE-MINING INVENTORY & ANALYSIS
MINING & REHABILITATION PLANNING & IMPLEMENTATION

AGGREGATE MINE REHABILITATION PLANNING MODEL

LEGEND:
1 ▪ Proposed Land Disturbance
2 ▪ Licensure to Mine
3 ▪ Land Management Objectives
4 ▪ Policy Development
5 ▪ Mining Opportunities
6 ▪ Rehabilitation Planning Objectives
7 ▪ Mining Objectives
8 ▪ Administrative Issues
9 ▪ Pre-mining Planning
10 ▪ Assessment of Produced Alternatives & Possible Compatible Land Uses (APAPCC) & Matrix A
11 ▪ Estimated Costs
12 ▪ Regional Analysis
13 ▪ APAPCC & Matrix B
14 ▪ Site Inventory & Analysis
15 ▪ Clearing, Stripping & Overburden Analysis
16 ▪ Visual Resources Inventory & Analysis Design Principles & User Management
17 ▪ APAPCC & Matrix C
18 ▪ Matrices Weighting & Outline of Design Criteria for the Selected Land Uses
19 ▪ Negotiations with the Town Planner, Operator & Landscape Architect
20 ▪ Preliminary Mining Plan Analysis
21 ▪ Review Reclamation Objectives & Ultimate Land Use
22 ▪ Assessment of Potential Impact of the Mining Operation on the Environment
23 ▪ Identification of Potential Problems caused by Mining.
24 ▪ Post-Mining Land Use Plan
25 ▪ Planning Design
26 ▪ Mining Operations
27 ▪ Site Preparation & Improvement During Operations, & for Future Land Use
28 ▪ Site Maintenance
29 ▪ Soil Amelioration Practices
30 ▪ Rehabilitation
31 ▪ Revegetation Plan
32 ▪ Mining Plan
33 ▪ Reclamation Materials Handling Plan
34 ▪ Post-Mining Contour Map
35 ▪ Final Costs
36 ▪ Final Reclamation Plan
37 ▪ Site or Master Plan
38 ▪ Development Staging
39 ▪ Refinement of the Plan in Detail
40 ▪ Monitoring
41 ▪ Overall Review


TEST A
23
NO PROBLEMS
PROBLEMS DUE TO THE MINING PROCESS
PROBLEMS DUE TO SITE CHARACTERISTICS
MODIFICATION OF THE MINING PROCESS
UNSUCCESSFUL
RE-EVALUATE THE PROBLEM
SUCCESSFUL
MODIFICATION OF OVERBURDEN HANDLING TECHNIQUES OR TREATMENT OF THE LIMITING CHARACTERISTICS OF OVERBURDEN AND SITE
UNSUCCESSFUL
RE-EVALUATE THE PROBLEM
SUCCESSFUL


31
CONDUCT GROWTH TRIALS
UNSUCCESSFUL
SUCCESSFUL
Conduct a Feasibility Study
RE-EVALUATE THE PROBLEM
Not Acceptable
Acceptable
SEEK AN ALTERNATIVE
Full scale Revegetation
Post vegetation Management
TEST B

the rehabilitation program and its costs. Policies should respond to the proposed land management objectives, should state desired land use(s) and establish an administrative framework for the project.

Step 5 or Mining Opportunities

The operator should outline the above during and after operations. Aggregate mining can result in two types of operation, wet or dry, of which each has its assets and drawbacks. Final land use will be determined by which is chosen. Six types of land normally result from a sand and gravel extraction operation. (Bauer, 1965).

1. Essentially level land with one or more lakes.

2. Level land readily adapted to large building sites.

3. Irregular land adaptable to large buildings with considerable regrading, or for smaller buildings with minimal regrading.

4. Steep land adaptable with extensive regrading for small building sites.

5. Deep pits suitable for special multi-storied buildings.

6. Land for conservation uses similar to the above."

Step 6 or Rehabilitation-Planning Objectives

These outline the Technical solution that is to be achieved. The desired degree of rehabilitation will determine the extent of site investigation, site planning, design process, and techniques to be used as well as the type of plant species to be selected. Some of the choices confronting the industry are: natural regeneration, restoration, rehabilitation, and reclamation.

Step 7 or Mining Objectives

The overall goal is for the rehabilitation operation to be an integral part of the mining operation. How it is integrated will depend upon the nature of the mining operation, the site, and the environment. Mining objectives should be outlined earlier in the operation process and reviewed.

Bauer (1971) lists the following common objectives of aggregate mining rehabilitation.

1. Minimize objectionable operational characteris- tics.

2. Improve the appearance of the mine area during and after operations.

3. Aim for efficient use of available equipment, earth material, and site characteristics, in an effort to develop the highest economic potential of the mined-out site.

4. Create visible land areas and therefore more valuable real estate for the after-use of minded-out sites.

Step 8 or Administrative Issues

Rehabilitation objectives and administrative objectives should be established at the same time in order to prevent political delays, excessive costs, and environmental deterioration.

Some examples of administrative issues are: capital costs, operational costs, scheduling, staffing, policy implications, and communications.

Step 9 or Preliminary Planning

During this phase it is important to evaluate the aggregate depth, value and deposit size, and how it is to be mined. At this stage the operator/owner should consider the following:

1. The objectives of the mine's rehabilitation program.

2. The land use(s) of the rehabilitative area during and after mining.

3. The inclusion of a thorough inventory of the landscape surrounding the mine.

4. An assessment of the impact the mine is likely to have on the environment.

Step 10 or Assessment of Possible
Compatible Land Uses (Operator's/Owners)

At this stage a matrix showing the owner's/operator's suggested final land use(s) is produced (Matrix A). From the land use matrix, weighting of the different parameters involved is done.

Step 11 or Estimated Costs

After the assessment of possible compatible land use(s) and the administrative objectives are understood and agreed, an estimated cost should be drafted, to give the developer a basis for his financial planning for mining and rehabilitation operations.

Step 12 or Regional Analysis and Assessment of
& Step 13 Possible Compatible Land Use(s)
(Regional)

For a successful rehabilitation plan, not only is a study of the mine site required, but also an understanding of its regional context.

The regional analysis should include: an evaluation of future regional land use needs, existing land use(s) on adjacent and nearby lands; regional master plan proposals for the preservation of valuable resources; demographic growth trends; economic trends in the area and local municipal and public needs.

After the regional analysis is completed a matrix of possible future land use(s) considering regional needs and public preferences should be prepared (Matrix B).

Step 14 or Site Inventory and Analysis

Here the existing uses and productivity potential of the land should be assessed. Information gathering should cover site resources, the surrounding environment, the deposit, and the type of operations proposed. The extensiveness of the site inventory and analysis should correspond to the needs and the objectives of the rehabilitation program, to avoid unnecessary exhaustive scientific evaluations. Sites that are designated as environmentally sensitive, highly visually scenic, or that may be drastically disturbed clearly will require a more thorough inventory than the more normal rural site in agricultural use.

It is to the advantage of the mine developer to determine early in the process what is to be the final land use. This early determination will save time, money and effort, in addition to speeding government permissions. Most rehabilitation projects have as a goal the restoration of the site to its previous land use or productivity. However, there are cases where the land can be turned to an improved use following mining.

A detailed inventory of the site plays an essential role, in providing a baseline from which the impacts of mining operation can be assessed and future land use options evaluated. Site inventory and analysis components include:

a) Detailed description of the site i.e. location, existing land uses, zoning regulations, etc.

b) Detailed description of the environment

   - vegetation
   - drainage hydrology
   - surface hydrology
   - chemical characteristics of water
   - topography
   - geotechnical information
   - soil investigations
   - wildlife
   - air quality

c) Detailed description of the deposit, amount of topsoil, gravel, overburden.

d) Detailed description of the mining operation.

Step 15 or Clearing, stripping and overburden analysis

At this stage a thorough assessment of the chemical, physical, and biological characteristics of the overburden, bedrock and regolith is done. (Regolith is unconsolidated mantle of weathered rock and soil materials above the bedrock.) Topsoil quantity and quality are assessed to determine if it is worthwhile having it stripped selectively and storing it separately. while clearing of existing vegetation is necessary to provide access for mining equipment, this should be done selectively in order to leave intact outstanding trees (vigorous with good reproduction, or aesthetically pleasing), shelterbelts, and visual screens, rather than the common and more expensive approach of clearing and planting where vegetation could have been saved. The following sequence is suggested:

- selective clearing
- selective salvage of vegetation
- clearing and gubbing of extraction site
- topsoil removal, stockpile, or transfer
- subsoil removal, stockpile, or transfer
- overburden stripping and transfer

- material excavation (aggregate)
- aggregate crushing and screening
- stockpiling or aggregates
- transfer and use of aggregates

Step 16 or Visual Resources Inventory and Analysis, Design Principles and User Management

Visual resources should be analyzed both prior to and following disturbance.

The depth of the study will depend on the extent of detail necessary, the area of land to be disturbed and the site's future land use(s).

Design principles are directly related to visual resources, and are utilized during site planning and design to accomplish the aesthetic goals of the rehabilitation project. Design principles can be utilized to modify the visual effect of derelict land, as well as to reshape natural forms, create new shapes, produce different land uses, create moods, and generally produce a landscape as visually pleasing as it was prior to mining or more so. Some common design components include: proportion and scale, spatial relationships, unity and composition, sequence, balance, form, shape, orientation, texture and pattern, colour enframement, rhythm, contrast, variety, convergence, dominance and co-dominance.

User management is required in order to protect the site from overuse such as overcrowding of recreation sites, overgrazing of pastures. A study of ways to avoid this problem is important to ensure that the rehabilitated site will not be damaged. some measures commonly taken are: site zoning; movement barriers; fixed trails; flood boundary definition; good signage; adequate site facilities development; access control; well-designed pedestrian and vehicle flow, and so on.

Step 17 or Assessment of Possible Compatible Land Uses (Site's)

After the site's inventory and analysis is completed (step 14), its information together with: the rehabilitation planning objectives (step 6), the information of clearing, stripping and overburden analysis, visual resources inventory-analysis and design principles and user management (step 16), a matrix (Matrix C) will be produced which is the site's (as indicated by the biophysical determination) suitability to sustain certain proposed final land use(s).

Step 18 or Matrices Weighting

After the matrices of the owner/operator's suggested land use(s), (Matrix A) and regional-public suggested land use(s) (Matrix B) and the site's suitability for future land use(s) (Matrix C) are completed they are weighted and ranked.

Step 19 or Negotiations with the Town Planner, Operator and Landscape Architect

A meeting will then have to take place between the three parties involved, (owner/operator, regional planning committee, and site representative, i.e. the landscape architect) to agree upon uses to be selected, and the proportion of land to be allocated to each land use. Then the landscape architect should outline the design criteria for the selected land use(s) as agreed to by the above three parties.

Step 20 or Preliminary Mining Plan Analysis

During this phase it is important to calculate the total volume of overburden, sand, and gravel to be as well as the total volume of overburden and topsoil to be stored, for use in backfilling and root zone development.

It is also important at this stage to outline: the proposed pit limits and the final shape of the mined area; the proposed phasing of the mining operations showing areas proposed for development for each year of the pit's projected development; and the anticipated degrees and lengths of slopes.

Step 21 or Review of Reclamation Objectives and Ultimate Land Use

Step 22 or Assessment of the Potential Impact of the Mining Operation on the Environment

Step 23 or Identificaiton of Potential Problems Caused by Mining Test A - Assessment of problems due to mining

Step 24 or Post-Mining Land Use Plan

The information derived from the preliminary mining plan analysis, the review of the reclamation objectives and ultimate land use, the information on the assessment of the potential impact of the mining operation on the environment and the identification of problems caused by mining all together will produce the post-mining land use plan.

At this phase in the model the following objectives should be addressed:

1. Identify land Use(s) determinants and elaborate on the items which the producer through operations can control.

2. To suggest development techniques for the optimum use of mined land.

3. To suggest land use(s) the site is able to support and which are the most appropriate (see above explanation).

Step 25 or Planning Design

Here the information gathered relative to mining opportunities and that related to planning objectives come together. At this stage it is important to review the goals and objectives for both, to assess alternatives for mining and rehabilitation processes, and to delineate some future compatible uses.

Here one should take into account that the rehabilitation plan is not just an aesthetic solution or modification of earth-shapes vegetation patterns, water or other landscape elements, but rather a process that integrates, the ecological characteristics of the site, its rehabilitation objectives, and mining operation requirements.

At this stage the planner or landscape architect should:

1. Review all the feasible and suitable future land use(s)

2. Review the design criteria

3. Review the mining operations

4. Test the compatibility of land uses with regional, site and operator/owner needs; (see Matrix A, B and C)

5. Conclude which are the most suitable by outlining the topmost ranked land uses from the combination of the above

6. Specify in detail how mining and reclamation procedures will occur simultaneously

7. Address in a sketch format how the site will look after rehabilitation is completed

Step 26 Mining Operations

Mining operations will determine both the site plan and the final reclamation plan.

Key operational stages include: choice of equipment; stripping and stockpiling; establishment of operational plans; excavation of aggregates; landform shaping; land rehabilitation operations; and operations for the general improvement of the site. (Overburden, vegetation, mine construction and operation.)

Step 27 Site Preparation and Improvement During Operations, and for Future Land Use(s)

Most pits after mining lack an adequate surface for plants to thrive on. The following are some important factors to be considered in improving the pit for future plant establishment; landform improvement, wind protection, screening, snow management, road construction, among others.

Step 28 or Site Maintenance

During and after rehabilitation, the site should be properly maintained to ensure a successful rehabilitation program.

Important considerations include the following; weed control, thinning, pruning, watering, etc.

Step 29 Soil Amelioration Practices

Soil amelioration procedures include the following:

Fertilization
Placement of a ground cover (mulch, rock, vegetation, etc.)
Use of chemical binders and tackifiers to hold the soil
Irrigation

Step 30 Rehabilitation

The main goal of most aggregate mines is to accelerate the natural process, restoring the mined area to a balanced productive state. A rehabilitation program can be considered to be successful if it achieves the following:

> "Establishes a self-sustaining vegetation cover;
>
> Provides a vegetation ground cover that will co-exist with the natural vegetation and eventually be incorporated into the surrounding environment.
>
> Achieves the planned ultimate land use for the reclaimed land.
>
> Creates an environment that is at least of equal productivity, both ecological and of socio-economic value to the pre-mine conditions."
>
> (Bauer 1971)

Step 31 or Revegetation Plan

The revegetation plan should include the method and time frame required to manage and maintain initial and post-mining vegetation cover. At the same time, it should aim to result in good solid productivity and a self sustaining plant community. That will be able to develop to a self-sustaining stand of equal or greater productivity than that which existed prior to disturbance. This step also includes revegetation test plots.

During rehabilitation, test plots to try out different possible types of plant material should be established.

This plan should also include guidance as to species selection, assessment of vegetation productivity prior and after mining, collection of material, methods of seedbed preparation, bioengineering, methods and rates of seeding and fertilization, site preparation, selection of techniques to be used for planting and seeding, scheduling ecological succession and stability etc.

Step 32 or Mining Plan

The information in this plan is derived from the total amount of overburden to be mined, the volume of overburden to be stored for backfilling and root zone development, the amount of deposit to be mined, and the presence of bedrock or ground water tables.

Studies at this stage include:

-screening requirements on the site
-suitable location for the processing plant with
  respect to efficient mining practices and
  compatibility with adjacent lands

- desirable areas for building future landforms
- reclamation requirements
- stripping and stockpiling of topsoil and overburden patterns and landforms
- desirable excavation patterns with respect to efficient mining practices and compatibility with adjacent lands and efficient land shaping practices
- road layout
- the use of mining equipment in shaping the land
- ultimate shape of the mined-out deposit
- progressive mining and rehabilitation schedule

Step 33 or Reclamation Materials Handling Plan

The information on overburden analysis dealt with earlier is of prime importance here. The reclamation materials handling plan should deal with the use of all mined and/or excavated material on the site, including the material used for backfilling, storage and the depth of root zone formation. It is also important to isolate deleterious overburden material. This plan should also include in it sequencing and timing. During this phase the following studies should be undertaken:

Determination of locations and estimated volumes of topsoil and overburden

Storage locations for the above material

Volumes of topsoil to be used to aid in vegetation establishment

Equipment to be used:

sequencing
final topography to be achieved
erosion control measures
stockpile stability
optimal slope angles and highwalls

Surface hydrology analysis, related to material handling and storage

Effects of existing topography on future stability and reclamation

It is important in this phase to handle the overburden in a proper manner. In the handling plan, reshaping involves giving the land the necessary contours to allow for surface drainage as well as attempting to blend final shapes with those of surrounding features. The aim in this stage should be to leave the landscape to blend with its surroundings as much as possible.

Step 34 Post-Mining Contour Map

This map gives an idea of the final contours and future surface drainage pattern and any rehabilitation or production of new water bodies. Important factors to consider here are: topographic factors (aspect, slope, elevation); microclimate conditions; erosion problems; proposed land uses; topsoil; physical; chemical, and biological characteristics among others.

Step 35 of Final Costs

At this stage the final costs for rehabilitation and mining operations should be finalized and proper financing sought.

Step 36 of Final Reclamation Plan

The reclamation plan is the result of the integration of the final costs assessment mining plan, the surface drainage contour map, the reclamation materials handling plan, and the revegetation plan.

The final reclamation plan together with the operations (including site maintenance, site preparation and soil amelioration) planning, and design stages, will produce the site or master plan.

Step 37 or Site or Master Plan

The final plan is the crysol of the mining operations, rehabilitation, future land use(s) and design details.

Step 38 or Development Staging (Phasing)

In this phase one should outline graphically or verbally the phasing of the rehabilitation project.

Step 39 or Refinement of the Plan in Detail

Step 40 or Monitoring

After rehabilitation is completed the site should be maintained, and monitored. Care and control of the rehabilitation site are crucial during the immediate post mining phase to aid in vegetation establishment, prevent erosion, and reduce the incidence of pests, drought, vandalism and overuse of certain areas. Maintenance should commence early in the rehabilitation program. Some common maintenance processes include weed control, staking and guying, thinning, pruning, user control, watering, mowing, fencing, and so on.

Observation and evaluation of the success of rehabilitation is becoming important, since the results can be used to improve or modify the management of future rehabilitation. The commonest parameters that the industry has found to be worthwhile monitoring include: community productivity and dynamics, vandalism, species establishment, soil compaction, soil fertility, plant mortality and wildlife colonization among others.

Step 41 or Review

The review component in the model is present in each of its steps, in order to emphasize the importance of assessing as one goes along the success or failure of the rehabilitation program. The review process evaluates the technical and scientific aspects of rehabilitation, as well as examining the ongoing interaction with other components of the model. The review stage allows the developer to change the rehabilitation objectives as new needs and variables are encountered in the mining and rehabilitation process.

USE OF THE MODEL

I
The information gathered on the proposed Land Disturbance Application (1), the Licensure to Mine (2), The Land Management Objectives (3), The Policy Development (4), will furnish data from which the Mining Opportunities (5) and Rehabilitation Planning Objectives (6) may be produced.

II
The information on Mining Opportunities (5) should be combined with Mining Operations Information (26), Mining Objectives (7), Administrative Issues (8), Pre-mining Planning (9), and Estimated Costs (11) to derive the information needed to create the Assessment of Possible Compatible Land Uses (owner's/operator's desires) (10).

This information will assist in the production of Matrix A, which is the owner's/operators suggested final land use(s).

III

The Regional Analysis, and Public Needs Information (12), is assessed and dealt with in the Assessment of Possible Compatible Land Use(s) (13). This information will assist in the production of Matrix B (Regional Needs and Public Desires).

IV

Rehabilitation Planning Objectives (6), together with the information on Site Inventory and Analysis (14); Clearing, Stripping and Overburden Analysis (15); Visual Resources Inventory-Analysis, Design Principles, and User Management (16) will produce information that should be dealt with in the Assessment of Possible Compatible Uses (suitability of the site) (17). This information will aid in the derivation of Matrix C which is the site's suitability for certain land uses.

V

Matrix A (10), Matrix B (13) and Matrix C (17), are weighted, combined, and assessed in step (18) to determine the most appropriate future land use(s) in terms of operator preference, regional and public preference, and the capability of the site.

Matrices A, B and C consist of two axes along each of which are spread 35 alternative land uses. These will be seen to be a comprehensive listing of possible uses for virtually any site. This listing covers uses that are regularly mentioned in rehabilitation - related literature, and also draws on the author's experience in and exposure to the rehabilitation field. Other uses, of course, could be added and the listing should respond to site specific conditions in each application.

The three matrices would be constructed as follows: Matrix A by the Operator/Owner, Matrix B by the Regional Planning Committee or Municipality and Matrix C by the environmental planner or Landscape Architect.

Matrices are then weighted according to specific criteria. A comprehensive determination of preferred land uses will be arrived at by adding the totals for each land use from each of the three matrices. Subsequently, a list is drawn up ranking land uses from highest score to lowest. A meeting will then have to take place between the three parties involved, step (19), (Owner/Operator, Regional Planning Committee and Site Representative, i.e. the Landscape Architect), to agree upon uses to be selected and the proportion of land to be allocated to each land use.

The designer then assesses the agreement arrived at in combination with the municipal policies and land use standards to generate design information and criteria for the Master Plan.

VI

This information (19) is then carried to the Preliminary Mining Plan Analysis (20), and then reviewed at the Review of Reclamation Objectives and Ultimate Land Use (21).

VII

The information from (20) and (21) together with, a) the information produced on the Assessment of Potential Impacts of the Mining Operation on the Environment (22) and b) the Identification of Potential Problems Caused by Mining (23) will produce the Post-Mining Land Use Plan (24).

VIII

The Post-Mining Land Use Plan (24) with the Outline of Design Criteria for the Selected Land Uses (Matrix A, B and C) (18) and the result from the negotiations (19) together with the Mining Operations (26) will give the Planning Design (25).

IX

The Planning Design (25), Final Costs (35); the Rehabilitation Program (30) and its subheadings, Revegetation Plan (31), Mining Plan (33) and the Post-Mining (34) will give the Final Reclamation Plan (36).

X

Mining Operations Information (26) together with Site Preparation and Improvement During Operations and for Future Land Use(s) (27), Site Maintenance (28), Soil Amelioration practices (29), Planning Design (25) and Final Reclamation Plan (36), will produce the Site Plan or Master Plan (37).

XI

Here the ~~developing~~ staging (phasing) of the Master Plan is fully described verbally or graphically (38).

XII

The Master Plan then can be further Refined and Detailed in (39).

XIII

Monitoring (40) is an important phase after rehabilitation is completed, to ensure results are satisfactory. As a final stage an Overall Review (41) is indispensible, to supplement the reviews of individual steps throughout the process and to indicate areas where modifications may be desirable for future applications.

The model has been used to derive the River-view Rehabilitation Master Plan (a sand and gravel operation currently in operation in Alberta). The model helped to organize the information allowing for progressive rehabilitation to occur.

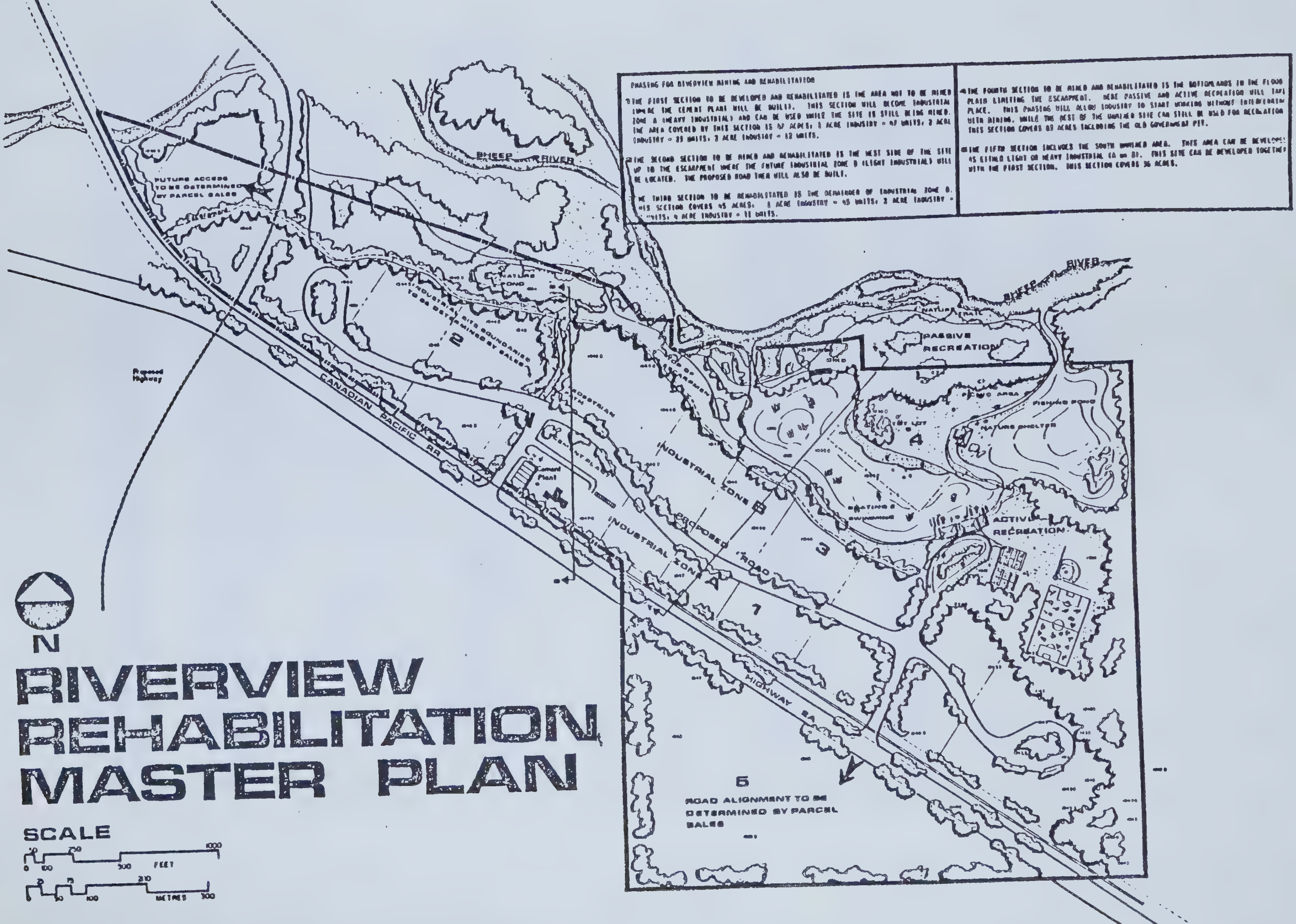
To sum up, the A.M.R.P.M. Model provides a guide and orientation which someone in the aggregate industry and research could follow in the rehabilitation process toward the ends of satisfying both government requirements and owner's desires as well as respecting the environment.

LITERATURE CITED

Bauer, Anthony, M. "Simultaneous Excavation and Rehabilitation of Sand and Gravel Sites," The National Sand and Gravel Association, Silver Springs, Maryland, 1965.

Bauer, Anthony, M. "A Guide to Site Development and Rehabilitation of Pits and quarries; Ontario Department of Mines, Mines Publications Office, Ontario Ministry of Natural Resources, Parliament Building, Queen's Park, Toronto, Ontario. 1971.

APPLICATION OF THE MODEL ON A SITE


FUTURE ACCESS TO BE DETERMINED BY PARCEL SALES
SHEEP RIVER
Proposed Highway
NATURE POND
INDUSTRIAL SITES BOUNDARIES TO BE DETERMINED BY SALES
PEDESTRIAN PATH
CANADIAN PACIFIC RR
Cement Plant
2
INDUSTRIAL ZONE B
INDUSTRIAL ZONE A
PROPOSED ROAD
3
1
PASSIVE RECREATION
NATURE TRAIL
SHEEP RIVER
PICNIC AREA
FISHING POND
NATURE SHELTER
4
BOATING & SWIMMING
ACTIVE RECREATION
HIGHWAY 2A
5
ROAD ALIGNMENT TO BE DETERMINED BY PARCEL SALES
N
SCALE
0
100
250
500
1000
FEET
0
30
75
150
210
300
METRES

RIVERVIEW REHABILITATION MASTER PLAN

PHASING FOR RIVERVIEW MINING AND REHABILITATION

① THE FIRST SECTION TO BE DEVELOPED AND REHABILITATED IS THE AREA NOT TO BE MINED (WHERE THE CEMENT PLANT WILL BE BUILT). THIS SECTION WILL BECOME INDUSTRIAL ZONE A (HEAVY INDUSTRIAL) AND CAN BE USED WHILE THE SITE IS STILL BEING MINED. THE AREA COVERED BY THIS SECTION IS 57 ACRES: 1 ACRE INDUSTRY = 47 UNITS, 2 ACRE INDUSTRY = 23 UNITS, 3 ACRE INDUSTRY = 12 UNITS.

② THE SECOND SECTION TO BE MINED AND REHABILITATED IS THE WEST SIDE OF THE SITE UP TO THE ESCARPMENT WHERE THE FUTURE INDUSTRIAL ZONE B (LIGHT INDUSTRIAL) WILL BE LOCATED. THE PROPOSED ROAD THEN WILL ALSO BE BUILT.

③ THE THIRD SECTION TO BE REHABILITATED IS THE REMAINDER OF INDUSTRIAL ZONE B. THIS SECTION COVERS 45 ACRES: 1 ACRE INDUSTRY = 45 UNITS, 2 ACRE INDUSTRY = [illegible] UNITS, 4 ACRE INDUSTRY = 11 UNITS.

④ THE FOURTH SECTION TO BE MINED AND REHABILITATED IS THE BOTTOMLANDS IN THE FLOOD PLAIN LIMITING THE ESCARPMENT. HERE PASSIVE AND ACTIVE RECREATION WILL TAKE PLACE. THIS PHASING WILL ALLOW INDUSTRY TO START WORKING WITHOUT INTERFERING WITH MINING, WHILE THE REST OF THE UNMINED SITE CAN STILL BE USED FOR RECREATION. THIS SECTION COVERS 83 ACRES INCLUDING THE OLD GOVERNMENT PIT.

⑤ THE FIFTH SECTION INCLUDES THE SOUTH UNMINED AREA. THIS AREA CAN BE DEVELOPED AS EITHER LIGHT OR HEAVY INDUSTRIAL (A or B). THIS SITE CAN BE DEVELOPED TOGETHER WITH THE FIRST SECTION. THIS SECTION COVERS 36 ACRES.

SESSION IV

PITS AND QUARRIES

Mr. R. Cook - Chairman

MANAGING ONTARIO'S AGGREGATE RESOURCES IN THE 80's - PROVINCIAL POLICY AND LEGISLATION

by

J.S. Masham[1]

and

N.P. Wood[2]

Ontario Ministry of Natural Resources

August 1983

ABSTRACT

The past decade has seen the government of Ontario become increasingly concerned with the management of the Province's mineral aggregate resources. Initially, government involvement concentrated on the regulation of the aggregate industry by means of legislation known as the Pits and Quarries Control Act. Passed in 1971, the intent of the Act was to regulate the operarion of pits and quarries and provide for rehabilitation. However, despite considerable improvements brought about by the Act, difficulties with enforcement and resource planning still existed. Consequently, in 1975, the Ontario Mineral Aggregate Working Party was established to examine the situation and suggest alternatives. The findings of the Working Party prompted the development of a dual program approach to aggregate resource management in this Province. A proposed Aggregates Act and a Mineral Aggregate Resource Planning Policy are the two primary components of this management strategy. The new Act will replace the Pits and Quarries Control Act providing for more stringent control of pit and quarry operations and their rehabilitation. The Planning Policy provides a framework for the planning of aggregate resources and extraction, primarily through the municipal planning process. It is anticipated, that when implemented, this dual approach will prove to be effective in ensuring that aggregates continue to be available at reasonable cost, while protecting local residents and the environment from the adverse impacts of extraction.

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[1] Aggregate Enforcement Policy Advisor, Industrial Minerals Section, Mineral Resources Branch.

[2] Geological Assistant, Industrial Minerals Section, Mineral Resources Branch.

INTRODUCTION

Ontario represents the highest demand area for mineral aggregate of any region in Canada. In 1980, 120 million tonnes or 14 tonnes per capita were used in the Province (Ontario Ministry of Natural Resources, 1980). The majority of this tonnage was produced and consumed in the southern part of Ontario (Fig.1), where 88% of the province's 8.5 million people reside (Ontario Ministry of Municipal Affairs and Housing, 1982).

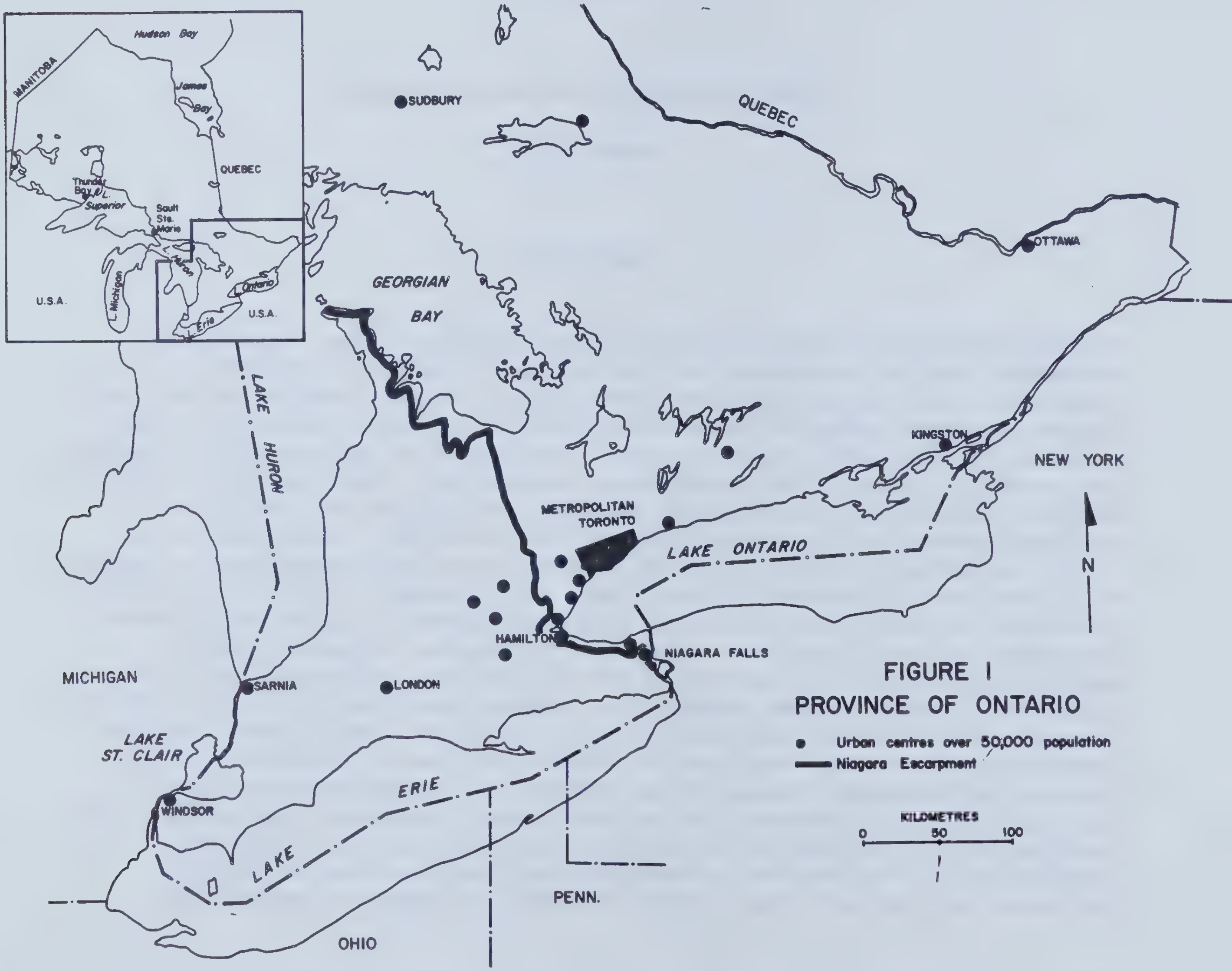
FIGURE I
PROVINCE OF ONTARIO

● Urban centres over 50,000 population
▬ Niagara Escarpment
KILOMETRES
0
50
100
N
Hudson Bay
MANITOBA
James Bay
QUEBEC
Thunder Bay
L. Superior
Sault Ste. Marie
L. Michigan
Huron
Ontario
Erie
U.S.A.
U.S.A.
SUDBURY
QUEBEC
OTTAWA
GEORGIAN BAY
LAKE HURON
KINGSTON
NEW YORK
METROPOLITAN TORONTO
LAKE ONTARIO
HAMILTON
NIAGARA FALLS
MICHIGAN
SARNIA
LONDON
LAKE ST. CLAIR
WINDSOR
LAKE ERIE
PENN.
OHIO

Metropolitan Toronto, and the surrounding regional municipalities of Peel, York and Durham constitute the largest market for sand, gravel and crushed stone in the Province, consuming approximately 32 million tonnes per year (Ontario Ministry of Natural Resources, 1982).

There are two primary sources of mineral aggregate in Ontario. One is the sand and gravel deposits of glacio-fluvial and glacio-lacustrine origin which includes outwash plains, outwash channels, kames, eskers and glacial lake deposits. Mostly formed in the late Wisconsinan phase of the Pleistocene epoch, between 7,000 and 16,000 years ago, these deposits are unevenly distributed throughout Ontario. The other major source of aggregate, in the Province, is the Paleozoic sedimentary bedrock underlying most of southern Ontario. The Niagara Escarpment, a south-westerly dipping cuesta capped by a Silurian dolostone, forms the most important bedrock source (Fig.1).

The tremendous demand for sand, gravel and crushed stone, in proximity to major urban centers, caused numerous problems which led to the Government of Ontario's involvement in mineral aggregate resource management. This paper will examine the Province's continuing and necessary role in the management of this finite, non-renewable and vital resource. Discussion will centre on mineral aggregate resource management in the 80's. The basic provincial management tools of legislation and policy will be examined, along with the province's work in the area of rehabilitation. Also presented, is a brief discussion on Ontario's past experience in the management of mineral aggregate resources.

HISTORICAL REVIEW

The Aggregate Industry

The aggregate industry's beginnings in Ontario are not well known, although it appears that gravel was used as a surface material on King Street in Toronto in or around 1826. At the end of the last century, the industry consisted primarily of small borrow pits scattered throughout the countryside. A few relatively large pits developed near some of the major urban centres such as Toronto, Ottawa and London, but even these were small in comparison to some of today's operations.

This situation more or less continued unchanged up to the middle of this century. However, by the 1950's, Ontario along with the rest of western world experienced an unprecedented surge in economic growth, a growth that was to be accompanied by vigorous construction activity and, consequently, an increased demand for aggregates. To achieve economies of scale and cope with sophisticated marketing techniques, large corporations and even multinational corporations joined the ranks, some producing as much as 5 million tonnes annually, at their various sites across the province.

Increasing environmental concern in the mid-1960's saw the focussing of attention on the effect of these operations on the natural environment. No meaningful provincial regulations existed at this time to effectively control such operations. As a consequence some members of the industry ran their operations in complete disregard for the environment, the rights of neighbouring landowners or their obligations as good corporate citizens. Since the 1950's, this problem has been compounded by an increasing rural non-farm population. As the number of exurbanites increased so did their effectiveness as an irritant to the aggregate industry. Responding to this pressure from exurbanites, many local municipalities enacted by-laws effectively prohibiting expansion of existing operations and establishment of new operations. By the late 1960's industry recognized the possibility of a shortage crisis and requested government to take remedial action, preferably in the form of legislation.

Legislation

The Provincial Government responded to industry's concern by establishing the Mineral Resources Committee in January, 1969. The first outcome of this Committee was the passage of the Niagara Escarpment Protection Act in 1970 (Province of Ontario, 1970). The Act was introduced as interim legislation to protect the Escarpment area pending passage of Province-wide pit and quarry legislation. A more detailed history of this legislation is presented in a previously published article (Yundt and Messerschmidt, 1979).

The Pits and Quarries Control Act was proclaimed on November 3 1971 (Province of Ontario, 1971). The intent of the Act was to provide rules and regulations that would accelerate rehabilitation and minimize the environmental impact of pit and quarry operations, while still providing for the aggregate requirements of the Province to be met within the Province. The Act is enforced by the Ministry of Natural Resources.

The Pits and Quarries Control Act and its regulations control the operation and rehabilitation of pits and quarries in municipalities of Ontario that have been designated by the Lieutenant Governor in Council by regulation. This Act now applies to those areas shown on Figure 2. This covers most of southern Ontario and the Sudbury and Sault Ste. Marie areas of northern Ontario. The designations correspond to the higher production areas (Fig. 3) and more urbanized areas (Fig. 1) of Ontario.

The licensing procedure established under the Act applies to large and small operations, whether they be commercial or farm-related. Temporary operations known as wayside pits and quarries required for specific road and highway projects are established by permit; a system that shortens the approval process considerably.

Under the terms of the Act, a licence application must be accompanied by a site plan which includes, among other things, progressive and ultimate pit development and rehabilitation. Somewhat less information is required for an operation producing less than 15,000 tonnes per year. This division was applied to protect the small businessman and to maintain the competitive nature of the industry.

An objection by anyone affected by the issuance of a licence requires the Minister to refer the matter to the Ontario Municipal Board, a quasi-judicial tribunal. The Minister may also refer the matter to the Board on his own, if he feels a hearing is warranted. A drawback to the licensing process is the length of time it takes for the necessary approvals. Two to five years and considerable sums of money are required to take an application through the Ontario Municipal Board hearing process.

With respect to rehabilitation, the regulations under the Pits and Quarries Control Act require that a security deposit of 8¢ per tonne of material removed from the property be paid to the Province. Payment into the fund must continue until such time as the licensee has a minimum of $1,000 on deposit per hectare of land requiring rehabilitation. Any surplus over and above the minimum amount required may then be claimed for expenses incurred in the rehabilitation of the site. If rehabilitation is not undertaken,

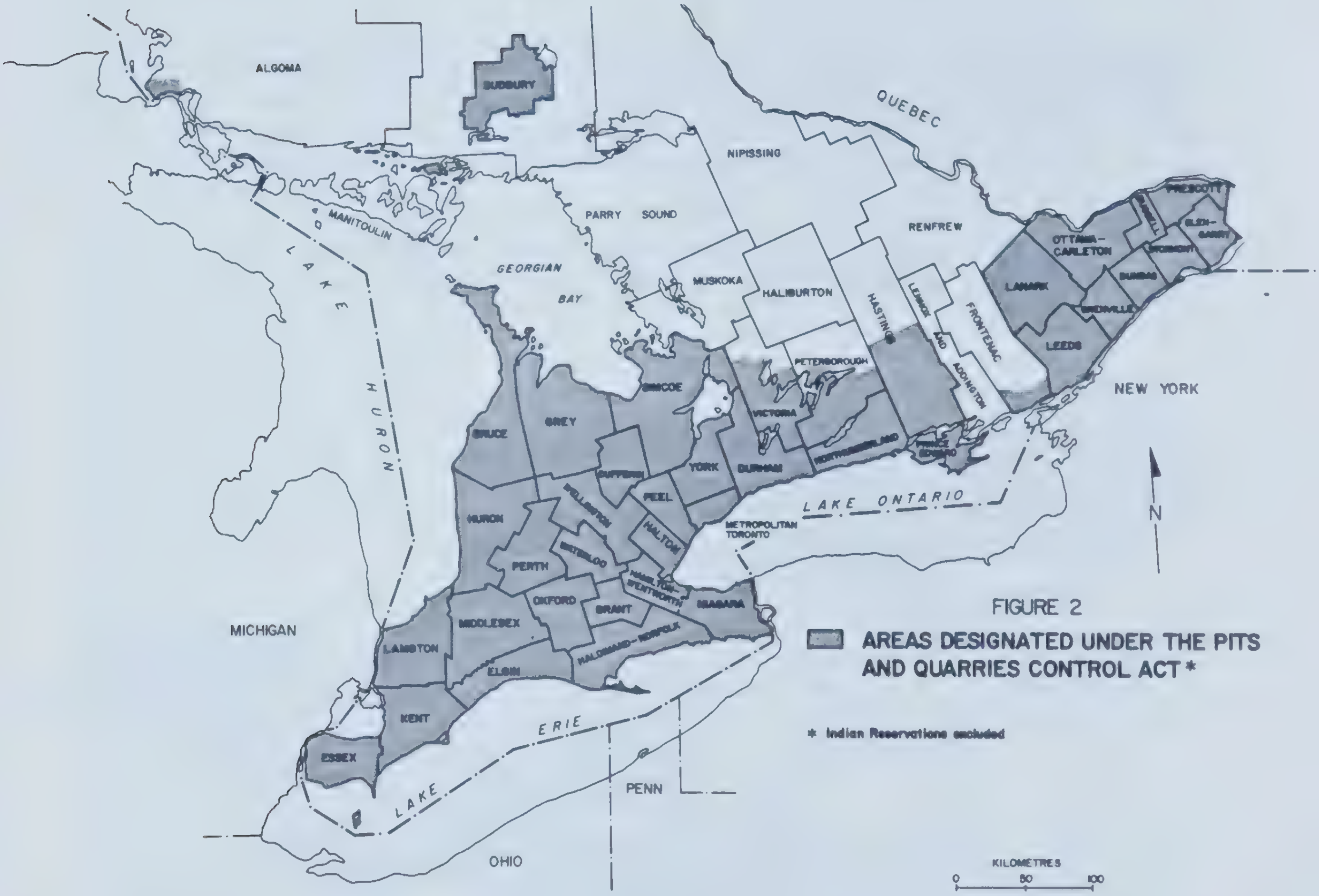
ALGOMA
SUDBURY
QUEBEC
NIPISSING
MANITOULIN
PARRY SOUND
RENFREW
PRESCOTT
RUSSELL
OTTAWA-CARLETON
GLENGARRY
STORMONT
DUNDAS
GRENVILLE
LANARK
LEEDS
GEORGIAN BAY
MUSKOKA
HALIBURTON
HASTINGS
LENNOX AND ADDINGTON
FRONTENAC
LAKE HURON
PETERBOROUGH
NEW YORK
SIMCOE
GREY
BRUCE
VICTORIA
NORTHUMBERLAND
PRINCE EDWARD
DUFFERIN
YORK
DURHAM
WELLINGTON
PEEL
HURON
LAKE ONTARIO
N
HALTON
METROPOLITAN TORONTO
PERTH
WATERLOO
HAMILTON-WENTWORTH
OXFORD
BRANT
NIAGARA
MIDDLESEX
MICHIGAN
HALDIMAND-NORFOLK
LAMBTON
ELGIN
KENT
LAKE ERIE
ESSEX
PENN
OHIO
KILOMETRES
0
50
100

FIGURE 2

▨ AREAS DESIGNATED UNDER THE PITS AND QUARRIES CONTROL ACT *

* Indian Reservations excluded

payment must continue to a maximum of $3,000 per hectare requiring rehabilitation. It is, therefore, to the aggregate producer's economic advantage to undertake progressive rehabilitation to reduce the size of the disturbed area and thus, maintain his security deposit at a minimum. Once rehabilitation is completed, any surplus remaining in the security deposit is refunded to the producer. If rehabilitation is not undertaken or not completed to the Ministry's satisfaction, the producer forfeits the money remaining in the account. This money is then used to rehabilitate the site.

Prior to January 1982, the security deposit was fixed at 2¢ per ton. Unfortunately, many producers considered the deposit so minimal that they simply regarded it as a tax. As a result, rehabilitation, if and when undertaken, was not always of a standard satisfactory to the Ministry. This led to problems of enforcement and eventually the security deposit was increased to reflect a more realistic average of rehabilitation costs.

As of March 1981, there were approximately 2,500 licensed pits and quarries in the designated municipalities covered by the legislation.

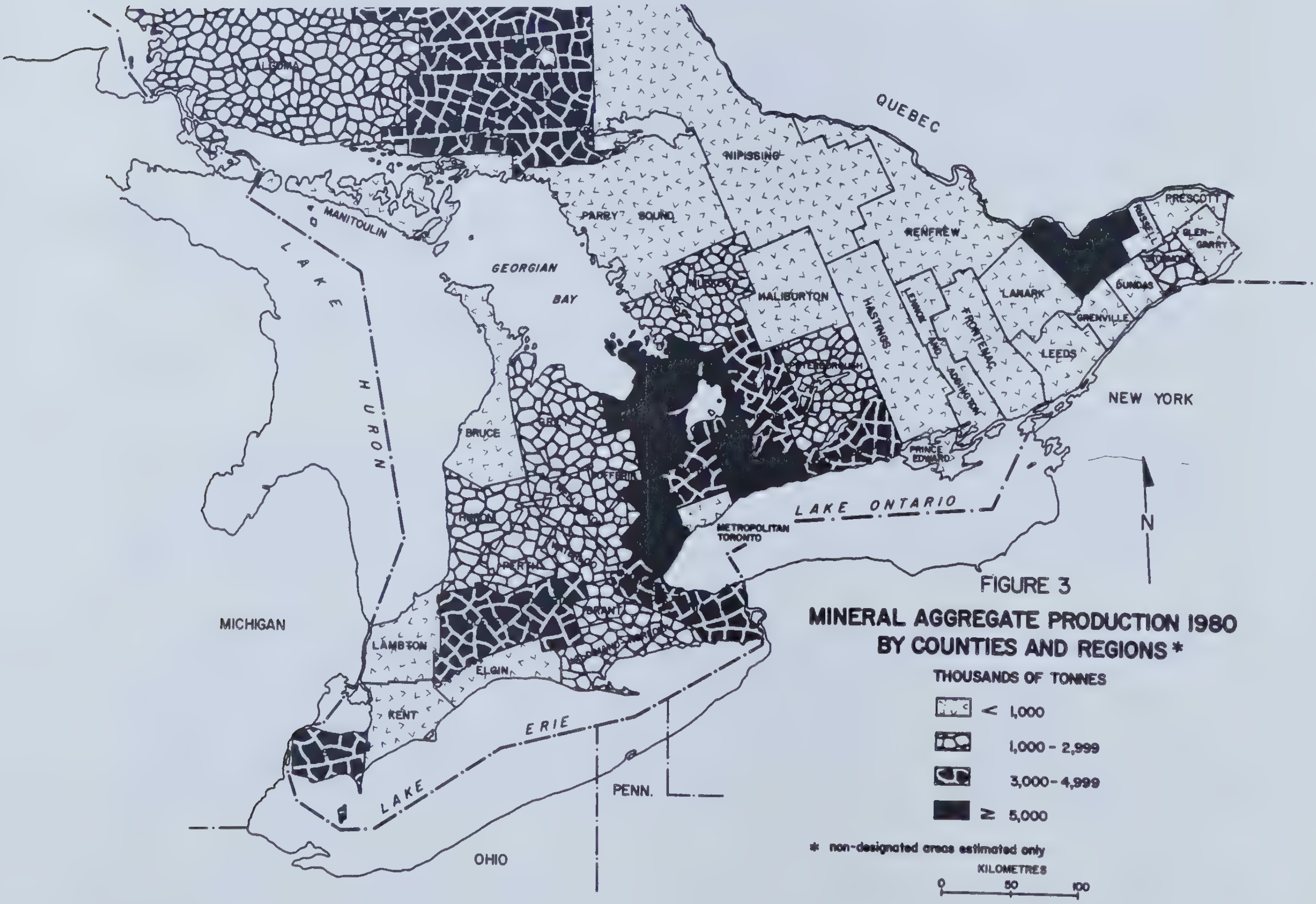
ALGOMA
QUEBEC
NIPISSING
MANITOULIN
PARRY SOUND
GEORGIAN BAY
RENFREW
PRESCOTT
RUSSELL
GLEN-GARRY
STORMONT
DUNDAS
GRENVILLE
LANARK
LEEDS
HALIBURTON
HASTINGS
LENNOX AND ADDINGTON
FRONTENAC
MUSKOKA
PETERBOROUGH
PRINCE EDWARD
NEW YORK
LAKE HURON
BRUCE
GREY
DUFFERIN
HURON
PERTH
WATERLOO
BRANT
LAMBTON
ELGIN
KENT
LAKE ONTARIO
METROPOLITAN TORONTO
MICHIGAN
LAKE ERIE
PENN.
OHIO
N
THOUSANDS OF TONNES
< 1,000
1,000 - 2,999
3,000 - 4,999
≥ 5,000
* non-designated areas estimated only
KILOMETRES
0
50
100

FIGURE 3

MINERAL AGGREGATE PRODUCTION 1980 BY COUNTIES AND REGIONS *

MANAGING ONTARIO'S MINERAL AGGREGATES IN THE 80's

Background

The past 11 years have demonstrated that there are many inadequacies in the Pits and Quarries Control Act. This is not to say that the Pits and Quarries Control Act has been an ineffective mechanism for the control and regulation of the aggregate industry in the Province. The past decade has seen Ontario achieve objectives in the regulation of aggregate operations that have taken Britain and Germany over 30 years to obtain. Research has indicated that since passage of the Act in 1971, the amount of rehabilitation has increased by 100% in the high production areas surrounding Toronto(Coates and Scott, 1979), and the quality of this rehabilitation is improving annually. A recent study conducted at the University of Guelph(Mackintosh and Mozuraitis, 1982) concludes that between 60% and 70% of all agricultural rehabilitation has been successful based on pre- and post-extractive soil capability classes; an impressive fact considering the industry's previous lack of experience in this area.

The weaknesses of the present Act became apparent over a period of years following problems in administration and enforcement. As a result, the Ontario Mineral Aggregate Working Party was appointed by the Provincial Government in December 1975 to examine the operations of the industry and the concerns of the municipalities. This method of formulating policy was a new concept to the Ministry of Natural Resources because all concerned parties were involved throughout the entire process. The fourteen Working Party members were selected to represent those groups most concerned with the problems associated with pits and quarries - regional and municipal councillors and staff, concerned ministries, industry and special interest groups such as the Niagara Escarpment Commission and the Conservation Council of Ontario.

The Working Party published its report, "A Mineral Aggregate Resource Management Policy for Ontario" in January of 1977 (Ontario Ministry of Natural Resources, 1977). The report contained sixty-four recommendations for new policy and legislation. After extensive review by a wide variety of interested groups and individuals, the Ministry of Natural Resources adopted 12 major guidelines, in general support of the Working Party's recommendations (Yundt and Messerschmidt, 1979).

These guidelines were adopted by Cabinet as government policy in March of 1978. They indicated, not only that new legislation was required, but that a provincial framework for the planning of mineral aggregate resources and the extractive industry was also necessary. Subsequently, the Ministry of Natural Resources has developed two separate, but complimentary programs in an aggregate resources management strategy for the Province of Ontario - new legislation and a planning policy. The proposed new legislation, known as the Aggregates Act, is not unlike the Pits and Quarries Control Act, in that it provides for the control and rehabilitation of pit and quarry operations, through a licensing process. This requires that operators follow standards set by the provincial government. The planning policy however, provides direction to municipalities regarding their planning for mineral aggregate resources and the aggregate industry.

The Aggregates Act

The Aggregates Act is designed to eliminate the weaknesses inherent in the Pits and Quarries Control Act. It is expected to replace the present Act in 1984. A number of sections and definitions in the Pits and Quarries Control Act have been reworded in the new legislation for clarification purposes. Also, new sections and definitions have been added to provide for better administration and enforcement. New provisions in the Aggregates Act provide for an increase in the quality and quantity of rehabilitation, including the rehabilitation of abandoned sites, more municipal liaison, municipal remuneration and power to suspend a licence. Pits and quarries on Crown land in designated areas will now come under this legislation as well.

Approval procedures under the Aggregates Act can be classified into four sections depending on the type of pit or quarry required:

1. Class A licence for commercial operations extracting more than 20,000 tonnes annually;
2. Class B licence for commercial operations extracting 20,000 tonnes or less annually;
3. Wayside pit and quarry permits; and
4. Crown aggregate permits.

Under the terms of the Aggregates Act, a Class A licence application must be accompanied by a site plan which must show:

(a) a key map showing the location of the site;
(b) a general description of the site, including lot and concession lines, if any;
(c) the shape, dimensions and hectarage of the site;
(d) the use of the land and the location and the use of the buildings and other structures within 150 metres of the site of the pit or within 500 metres of the site of the quarry;
(e) the location, dimensions and use of the buildings and other structures existing or proposed to be erected on the site;
(f) the location of the excavation setback limits;
(g) the location and type of fences;
(h) the location of tree screens and the species and types of the trees;
(i) the location of earth berms and their height and slope;
(j) any significant natural and man made features;
(k) the topography of the site including existing and estimated final contours and spot elevations;
(l) every entrance to and exit from the site;
(m) all roads on the site;
(n) the water table and any existing and proposed drainage facilities on the site;
(o) subject to available information, the location of water wells within 300 metres of the site;
(p) the maximum depth of excavation and whether it is intended to excavate below the water table;
(q) the sequence and direction of operation;
(r) the progressive rehabilitation and final rehabilitation plans; and
(s) any other necessary information respecting the site.

In making a decision whether to issue a licence, the Minister must have regard to the following criteria:

(a) the effect of the operation of the pit or quarry on the environment;
(b) the effect of the operation of the pit or quarry on nearby communities;
(c) any comments provided by the municipalities in which the site is located;
(d) the rehabilitation of the site;
(e) the suitability of the progressive rehabilitation and final rehabilitation plans having regard to the adjacent lands;
(f) any possible effects on ground and surface water resources;
(g) any possible effects of the operation of the pit or quarry on agricultural resources;
(h) the proper management of the aggregate resources of Ontario;
(i) any planning and land use consideratons;
(j) the main haulage routes to and from the site and the traffic density thereon;
(k) the quality and quantity of the aggregate on the site;
(l) the location and size of existing and proposed stockpiles of aggregate, topsoil and subsoil; and
(m) such other matters as he considers appropriate.

Additional terms and conditions may also be attached to the issuance of the licence. However, the Minister cannot issue a licence that is in contravention of a municipal zoning by-law. A better indication of the approval process for both a Class A licence and a Class B licence is shown in Figure 4.

The Aggregates Act also provides for:

1. Municipal Liaison: The Pits and Quarries Control Act does not require the Ministry to liaise with municipalities with regard to applications for a licence to operate a pit or quarry. The Aggregates Act will generally require consultation with municipalities and a review of site plans every five years.

2. Suspension of Licenses and Detailed Site Plan: Under the present Act the Minister may suspend a licence where the operation of the pit or quarry constitutes an immediate threat to the interests of the public. This does not provide for a method by which to deal with day to day violations of the Act or regulations. Although charges can be laid, this is a lengthy and costly procedure. It is proposed that the Aggregates Act will allow the Minister to suspend a licence immediately for any period of time up to three months, until the licensee has complied with the notice served upon him.

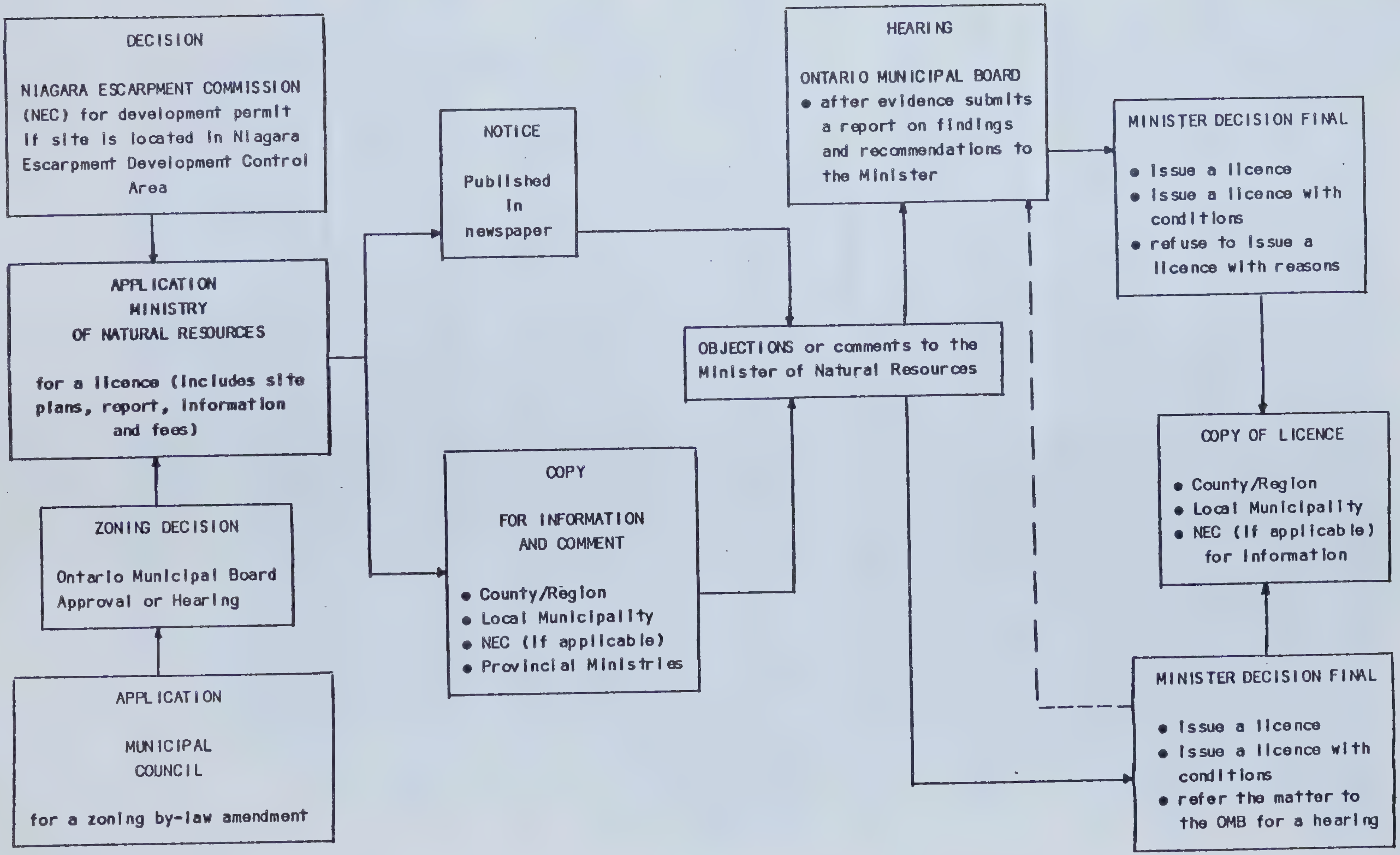
DECISION
NIAGARA ESCARPMENT COMMISSION (NEC) for development permit if site is located in Niagara Escarpment Development Control Area
APPLICATION
MINISTRY
OF NATURAL RESOURCES
for a licence (includes site plans, report, information and fees)
ZONING DECISION
Ontario Municipal Board Approval or Hearing
APPLICATION
MUNICIPAL
COUNCIL
for a zoning by-law amendment
NOTICE
Published in newspaper
COPY
FOR INFORMATION AND COMMENT
• County/Region
• Local Municipality
• NEC (if applicable)
• Provincial Ministries
OBJECTIONS or comments to the Minister of Natural Resources
HEARING
ONTARIO MUNICIPAL BOARD
• after evidence submits a report on findings and recommendations to the Minister
MINISTER DECISION FINAL
• issue a licence
• issue a licence with conditions
• refuse to issue a licence with reasons
COPY OF LICENCE
• County/Region
• Local Municipality
• NEC (if applicable) for information
MINISTER DECISION FINAL
• issue a licence
• issue a licence with conditions
• refer the matter to the OMB for a hearing

Fig. 4: The Aggregates Act: Licensing Process.

3. Remuneration to Municipalities: Over the years, local municipalities have maintained that they should be compensated for costs resulting from aggregate operations. The Working Party reviewed the problem and recommended that municipalities be compensated. This provision will be in the new Act. The annual licence fee under the new Act will be 6¢ per tonne with 4¢ going to the local municipality, 1/2¢ to the region or county, 1/2¢ to an abandoned pit and quarry rehabilitation fund and 1¢ to the Province.

4. Rehabilitation of Abandoned Pits and Quarries: The present Act has no provisions to deal with the rehabilitation of abandoned pits and quarries. The Aggregates Act will require that 1/2¢ of the annual 6¢ per tonne licence fee be set aside in a fund and disbursed for the purpose of conducting surveys or studies respecting the rehabilitation of abandoned pits and quarries and for the actual rehabilitation of the abandoned sites.

5. Crown Land Pits and Quarries: At the present time Crown land pits and quarries are administered under the terms of the Mining Act. As a result, in a designated area it is possible to have pits side by side administered under different legislation. The new legislation solves this problem and all pits and quarries in designated areas will come under the Aggregates Act.

6. Wayside Pits and Quarries: Wayside pits and quarries are temporary pits and quarries used by a public road authority for the purpose of a particular project of road construction. The Ministry of Transportation and Communications has hold-back provisions in their contract. The contractor is required to rehabilitate his pits in order to have the hold-back returned. Municipalities do not usually have these provisions in their contracts with the result that municipal pits are often left unrehabilitated. The Aggregates Act requires that before a permit is issued, municipalities shall deposit an amount equal to the number of tonnes authorized by the permit multiplied by 8¢ as rehabilitation security. When the rehabilitation is completed the money is refunded.

The Aggregates Act will provide more stringent controls and regulations, that will result in the improved planning and management of specific aggregate operations on site. It is not, however, intended to manage mineral aggregate resources on a regional or provincial scale or establish how or where pits and quarries may be located. To achieve this, the Ministry of Natural Resources has developed a planning policy that is implemented separately from both the present Pits and Quarries Control Act, and the proposed Aggregates Act.

Mineral Aggregate Resource Planning Policy

Although potential mineral aggregate resources exist in many parts of Ontario, a reduction in the availability of these resources is occurring in certain areas of the Province. The reduction of near market supplies is becoming serious and is not wholly connected with the depletion of the resources. Incompatible land uses (eg. housing, industrial and commercial developments) on top of, or adjacent to, deposits have effectively eliminated some valuable aggregate resources, while restrictive planning, legislation and other controls have also made the establishment and operation of pits and quarries difficult.

These problems were recognized and resulted in the establishment of a tri-ministerial committee in April of 1979. The committee, consisting of the Ministries of Natural Resources, Municipal Affairs and Housing, and Transportation and Communications, was given the responsibility of preparing an aggregate planning policy ("Mineral Aggregate Policy for Official Plans" or more commonly known as the 10-point policy. This policy was intended to provide direction for the municipal planning of mineral aggregate resources and the aggregate industry. Municipalities have the mandate for land use planning on private lands in Ontario, a role delegated to municipal governments by means of the Planning Act. The fundamental tools used to implement mineral aggregate policy at the local level are, therefore, official plans and zoning by-laws.

The 10-point policy was adopted by the Minister of Natural Resources in September, 1979 and was subsequently endorsed by Cabinet as Government policy. However, as with the Pits and Quarries Control Act, some problems with the wording of this policy became apparent. This led to the development of a new aggregate planning policy, the "Mineral Aggregate Resource Planning Policy" (MARP policy), which was approved by Cabinet in the closing days of 1982 and released in February 1983, together with a revision to the Food Land Guidelines (Government of Ontario 1982) concerning aggregate extraction in agricultural lands.

The MARP policy has benefited from full participation of all concerned parties, including interested citizens, public interest groups, aggregate producers and other government ministries. The policy establishes mineral aggregate resources as a matter of provincial interest and concern, and includes specific policies to ensure that due regard is paid to the importance of mineral aggregates and that the overall provincial interest is taken into account in any related planning matter. However, the policy does recognize that other matters such as forestry, agriculture, housing, recreation and environment must also receive consideration in land use planning at the municipal level. Furthermore, it is not intended to supersede or take priority over other provincial planning policies. Rather, it is designed to be implemented in conjunction with other relevant provincial policies and regulations, such as the Food Land Guidelines (Government of Ontario, 1978, 1982).

A number of principles have been recognized in developing Ontario's "Mineral Aggregate Resource Planning Policy". These principles form an integral part of the policy and are as follows:

1. Mineral aggregates are essential natural resources. Wherever they occur, they should be recognized as important components in any comprehensive land use or resource management program.

2. Mineral aggregates should be available to the consumers of Ontario at a reasonable cost.

3. All parts of Ontario possessing mineral aggregate resources share a responsibility for meeting future provincial demand.

4. Notwithstanding the need for mineral aggregates, it is essential to

environmental cost. In this regard there is a recognized need to develop policy and regulatory provisions that:

- a) establish good operating standards,
- b) ensure rehabilitation,
- c) establish evaluation and approval procedures for creating new operations and expanding existing operations.

5. The supply of mineral aggregates is essential to the overall development of any area. It is necessary to maintain sources of supply as close to markets as possible until such time as long distance transportation may become feasible.

6. In some instances other land uses, such as special agricultural uses, may take precedence over aggregate extraction, including wayside pits and quarries.

7. Wayside pits and quarries are needed on a temporary basis and often at short notice to supply mineral aggregates for certain projects of public authorities such as roads, at minimum cost to the taxpayer. They therefore require simplified planning and approval consideration.

8. Municipalities have an important role in planning for mineral aggregate resources and aggregate operations.

The policy establishes the role of official plans and zoning by-laws as they relate to aggregate resources and extractive operations, and defines the role of the Province in the management of these resources. The key elements of the Policy can be summarized as follows:

1. To recognize the importance of and to establish the Provincial interest in mineral aggregate resources.

2. To protect pits and quarries through municipal official plans and zoning by-laws.

3. To protect adequate mineral aggregate resources through official plans and zoning by-laws to allow options on future extraction to remain open.

4. To require official plans to provide a fair and workable process to consider the establishment of new pits and quarries.

5. To permit wayside pits and quarries without requiring an official plan amendment and generally without a zoning amendment (except in areas of existing development or particular environmental sensitivity).

6. To require policies in official plans which encourage rehabilitation to an after-use compatible with the long term uses permitted in the plan.

7. To establish the role of the Provincial Government with regard to aggregate planning and management including the provision of aggregate resource data such as mapping and input to the municipal planning process.

8. To establish how the Policy will be implemented.

In regard to implementation, the current planning process requires that a draft official plan be forwarded to the Ministry of Municipal Affairs and Housing for approval. At this point, it is circulated to concerned groups for comment, including the Ministry of Natural Resources. The Ministry reviews the proposed plan to ensure that it properly addresses the "Mineral Aggregate Resource Planning Policy", the main points of which are as previously stated. If these points are addressed adequately, the Ministry of Natural Resources' main concerns regarding planning for mineral aggregate resources and the aggregate industry are satisfied and the Ministry will not object to the official plan. Existing approved official plans and zoning by-laws will be amended to comply with this policy as they come up for review.

It should be noted that under the legislation (the Pits and Quarries Control Act and the proposed Aggregates Act) the Minister of Natural Resources cannot issue a licence to establish a pit or quarry where the location is in contravention of municipal zoning. Hence, the municipality, through its land use planning responsibilities, exercises control over the location of pits and quarries.

A new Planning Act, proclaimed on August 1st, 1983, provides for provincial interest in planning matters to be addressed through Provincial Policy Statements. It is expected that the Government's "Mineral Aggregate Resource Planning Policy" will soon be implemented in this manner.

Figure 5 illustrates the evolution of the dual approach to mineral aggregate resource management taken by the Ministry of Natural Resources - Legislation (the "Pits and Quarries Control Act" and the proposed "Aggregates Act") and planning policy (the "Mineral Aggregate Resource Planning Policy").

Rehabilitation and Research

The management of a resource does not stop with the adoption and enforcement of appropriate legislation and policy. Additional information is required if the proposed Aggregates Act and "Mineral Aggregate Resource Planning Policy" are to be implemented successfully. Rehabilitation is an important requirement of both the Act and the Policy and is perhaps the single most important factor in gaining public acceptance of the aggregate industry. Consequently, the Ministry of Natural Resources has been promoting rehabilitation since passage of the Pits and Quarries Control Act in 1971 and has undertaken many research and educational programs to assist operators in the rehabilitation of pits and quarries.

Extractive operations are rarely compatible with the surrounding landscape, with the result that they are quite visible to the public. This visibility is heightened by the fact that pits and quarries are generally located on the fringes of the more urbanized areas of the Province. However, the less visibly obtrusive the industry and the more compatible it is with its surroundings, the more it will demonstrate the operator's willingness to fit within the community framework. Rehabilitation satisfies two important objectives. It returns extractive sites to an after-use compatible with the surrounding landscape and makes more land available for other high priority land use requirements in urban fringe areas where land is at a premium. In these high demand areas, rehabilitated land can often be

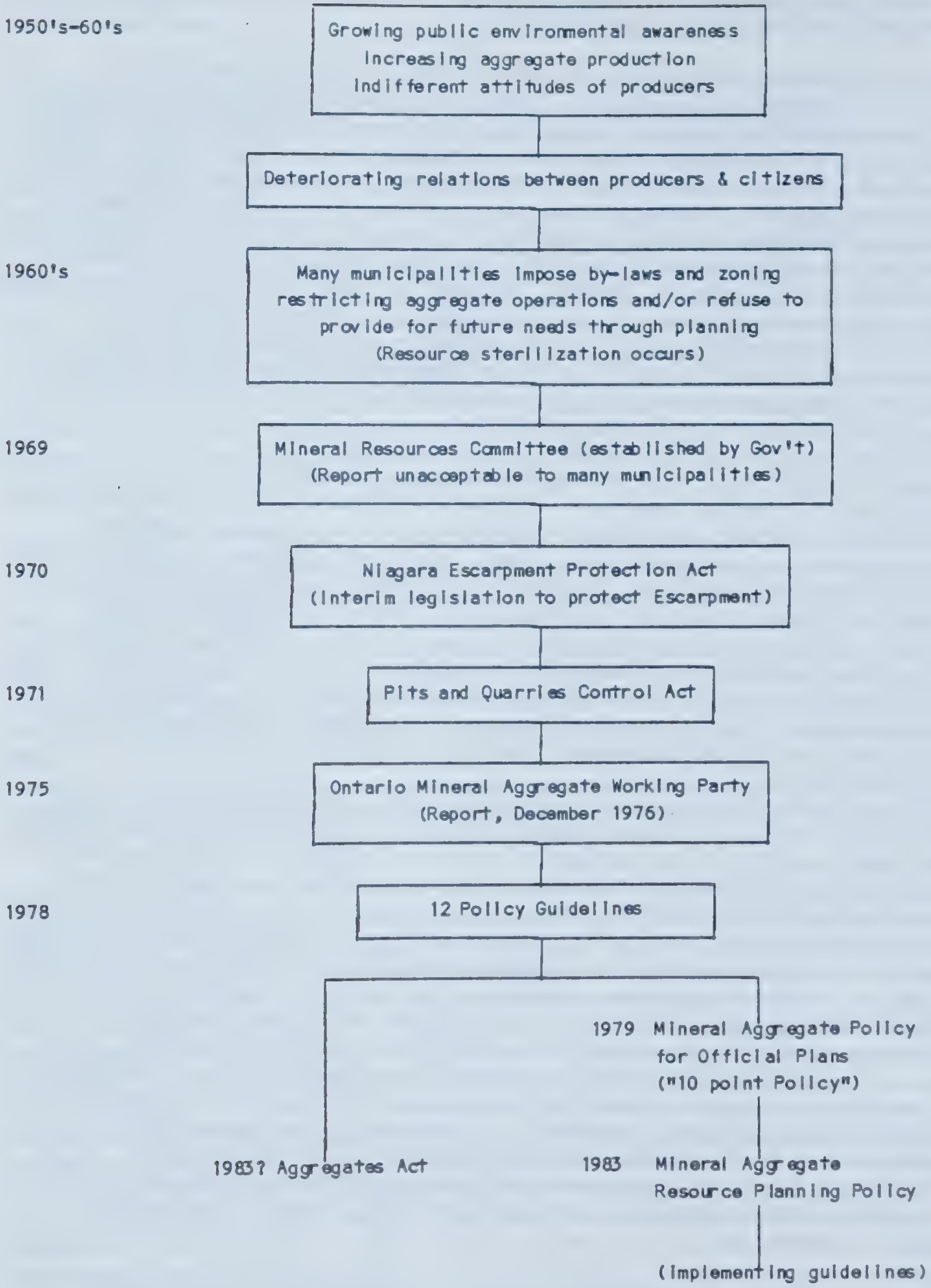
1950's-60's
Growing public environmental awareness
Increasing aggregate production
Indifferent attitudes of producers
Deteriorating relations between producers & citizens
1960's
Many municipalities impose by-laws and zoning restricting aggregate operations and/or refuse to provide for future needs through planning
(Resource sterilization occurs)
1969
Mineral Resources Committee (established by Gov't)
(Report unacceptable to many municipalities)
1970
Niagara Escarpment Protection Act
(Interim legislation to protect Escarpment)
1971
Pits and Quarries Control Act
1975
Ontario Mineral Aggregate Working Party
(Report, December 1976)
1978
12 Policy Guidelines
1979 Mineral Aggregate Policy for Official Plans
("10 point Policy")
1983? Aggregates Act
1983 Mineral Aggregate Resource Planning Policy
(implementing guidelines)

Fig. 5: History of Government Involvement in Mineral Aggregate Resource Management

incorporated into the overall land use pattern in a short time period, thus making rehabilitation highly desirable.

The benefits of rehabilitation have been recognized by the aggregate industry for a number of years now. Many excellent rehabilitation projects have been completed by conscientious operators eager to improve their public image. These projects range from housing estates and golf courses to tender fruit lands, the most challenging of after-uses. Unfortunately, however, not all operators view rehabilitation as a necessary and important part of the aggregate industry's total operation. This has resulted in an increase in the rehabilitation security deposit under the Pits and Quarries Control Act, as previously mentioned. Early indications show that the increase from 2¢/ton to 8¢/tonne has resulted in an increase in the amount of rehabilitation work undertaken (Ontario Ministry of Natural Resources, 1981). Similarly, the "Mineral Aggregate Resource Planning Policy" will assist through its requirements to have rehabilitation policies incorporated into the official plans of the municipalities.

Progressive rehabilitation will become mandatory under the proposed Aggregates Act and should lead to a further reduction in the total land area disturbed by extractive operations. Many aggregate producers already practice progressive rehabilitation simply because it is less costly in the long term. The equipment is on the site and can be used alternately for extraction and rehabilitation. In fact, an efficient and well planned progressive rehabilitation program will allow for the simultaneous use of equipment. Overburden and topsoil can be stripped from the active area and replaced on the area being rehabilitated, in one operation. This not only reduces the amount of overburden and topsoil that must be stockpiled, but also minimizes the active site area, thus, reducing its visibility.

The new Act will also allow for the rehabilitation of abandoned pits and quarries from a fund to be generated from the annual tonnage license fees as discussed previously. It is estimated that the 1/2¢/tonne contribution to this fund will permit the rehabilitation of most abandonded pits in the designated areas within 12 - 15 years. It will be the responsibility of the regional municipality or county to produce an inventory of abandoned sites, and establish priorities for their rehabilitation . The Ministry's District staff will be involved with most studies in an advisory capacity. When completed, a regional municipality or county can be reimbursed for the costs of such a study. It is presently envisioned that the fund will be administered centrally, with each Region of the Ministry being alloted an annual amount based on the extent of the problem within their jurisdiction with rehabilitation of the sites being undertaken by the Ministry or contractors. The fund is designed only to provide the basics of rehabilitation (ie. grading and seeding) and maintenance. Any additional amenities will be the sole responsibility of the landowner and/or the municipality concerned.

The Ministry of Natural Resources is not only interested in increasing the quantity of rehabilitation work undertaken, however. It is also equally concerned with the quality of that work. To this end, the Ministry has actively pursued a research program to assist aggregate producers in their rehabilitation efforts. This program was initiated in 1970, with the publication of Industrial Mineral Report 33(Bauer, 1970). Entitled "A Guide to Site Development and Rehabilitation of Pits and Quarries", it introduced

Ontario's aggregate producers to the advantages and techniques of rehabilitation.

Since that time, the Ministry has continued its investigations into the complexities of rehabilitation. In 1975, a report on the use of trees, shrubs, grasses and legumes in pit and quarry rehabilitation, entitled "Vegetation for the Rehabilitation of Pits and Quarries"(Ontario Ministry of Natural Resources, 1975), was released. Another report published in 1979 reviewed the quality and quantity of rehabilitation that had taken place since passage of the Pits and Quarries Control Act in 1971(Coates and Scott, 1979). In the same year, a comprehensive study entitled "Trees and Shrubs for the Improvement and Rehabilitation of Pits and Quarries in Ontario" was also released(Lowe, 1979). The Ministry has since published another study in the same series entitled "Agriculture and the Aggregate Industry" (Mackintosh and Mozuraitis, 1982). Conducted at the University of Guelph, this study details the procedures and techniques necessary for the successful rehabilitation of extracted sand and gravel lands to productive agriculture. Further research and publication in the area of rehabilitation of tender fruit lands is planned.

Several brochures have also been prepared for use by the general public. "From Pits to Playgrounds"(Yundt and Augaitis, 1979) is a publication intended to make the public aware of just how many former sand, gravel and clay pits, in Metropolitan Toronto, have been rehabilitated. The report is presented in the form of a tour guide to enable citizens to observe, first hand, what can be accomplished through rehabilitation. Over sixty sites are listed, all of which have been rehabilitated to a variety of uses, including recreational areas, residential estates, commercial malls and industrial parks. A similar educational brochure (Ontario Ministry of Natural Resources, 1980) briefly describes the state of the art of pit and quarry rehabilitation in Ontario, the legislation controlling the aggregate industry, and the importance of the industry to the Province's economy.

Since the success of any mineral aggregate management program depends on the actions and attitudes of the aggregate industry, municipalities, municipal associations and other groups, the Ministry of Natural Resources continually works to establish a close liaison with these groups. Recent efforts in this area have involved tours of extractive operations for local municipal and government officials to demonstrate the problems and characteristics of the aggregate industry. As well, tours of rehabilitated sites have been organized for various municipal associations, to show that the rehabilitation of pits and quarries can be successful, if approached in the proper manner. These tours are essential to an understanding of the aggregate industry. They allow municipal, provincial and federal officials, as well as the public, an opportunity to acquire first-hand knowledge of this vital industry, including operating practices, rehabilitation techniques and the actual use, and consequently the importance, of Ontario's aggregate resources.

The Ministry of Natural Resources is committed to ensuring full and progressive rehabilitation of all licensed and abandoned sites in the designated areas of the Province. The proposed Aggregates Act is designed to ensure such end results. However, the regulations under the Act are not so severe as to stifle competitiveness or drastically inflate consumer prices.

CONCLUSIONS

The Province of Ontario, through its Ministry of Natural Resources has been seriously working toward a comprehensive mineral aggregate management strategy for well over a decade. A great deal has been accomplished, but it fully realizes that there is a long way to go to achieve the ambitious goals of resource management embodied in the proposed Aggregates Act and the "Mineral Aggregate Resource Planning Policy".

In order to stay abreast of the industry and provide aggregate producers with the latest management techniques, innovations and mineral aggregate resource information, a vigorous research program has been maintained throughout the past eleven years. This has involved the expenditure of close to 1.5 million dollars in studies, ranging from the aforementioned research on rehabilitation techniques to aggregate demand forecasts and resource inventories. Combined with the Province's "Mineral Aggregate Resource Planning Policy" and proposed Aggregates Act these studies form an integral part of the Ministry's mineral aggregate resource management strategy and should prove excellent resource material for the aggregate industry, municipal governments and any agency considering a mineral aggregate management program.

To summarize, the Province of Ontario's efforts have been concentrated on controlling and regulating the aggregate industry by means of legislation over the past twelve years. Only during the past four years have efforts been directed towards protecting non-renewable aggregate resource by means of a mineral aggregate planning policy. The dual approach to mineral aggregate resource management consisting of the proposed Aggregates Act and "Mineral Aggregate Resource Planning Policy" will provide the Province of Ontario with one of the most advanced mineral aggregate management strategies in Canada, if not North America. It is anticipated that when fully implemented, this approach will prove to be a most effective mechanism for controlling the aggregate industry and preserving the Province's aggregate resources for the future.

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LAND RECLAMATION AND THE ONTARIO AGGREGATE INDUSTRY - AN UPDATE

by

Keith Watson of the Aggregate Producers' Association of Ontario

ABSTRACT

The sand, gravel and crushed stone industry has supplied the foundation for rapid growth in Ontario over the past thirty years. The close proximity of aggregate operations to urban demand centres is a necessity which has created ongoing social and physical complications. This meeting of people and pits has resulted in the aggregate producers and the Provincial Government taking co-operative pre-planning steps to encourage careful operational practices and thus, successful land reclamation.

Aggregate is not considered a household name even though it is one of the most widely used materials in modern society. By definition, the term "aggregate" is used by the industry to describe construction materials derived from natural sources and is commonly recognized as sand, gravel and crushed stone. Aggregate products range in size from large armour stone used for shoreline erosion control to fine ag-lime which helps farmers control soil acidity. Although it is most often used in road construction, aggregate is also used in the manufacturing of steel and glass.

In terms of tonnage produced, aggregate extraction represents by far the largest mining industry in Ontario. The dollar value derived from aggregate ranks it fourth in the mining industry behind nickel, copper and gold.

The growth of any city is dependent on sand and gravel as the basic building material. Nearly 80% of all concrete and asphalt mixes are composed of aggregate. About 11.5 metric tons of new aggregate will be used on behalf of every Ontario resident each year.

An average quarry operation, covering approximately 16 hectares in its lifetime, will produce enough aggregate to construct and service over 3,000 homes or build 40 kilometres of conventional paved roadway.

There are two ways of extracting aggregate from the ground - quarrying and pit mining. Each method, depending on the specific physical properties of the site and the community needs in the particular area, will face different problems when considering what the potential after-use will be.

Quarrying is the term used to describe the extraction of consolidated material or bedrock. Today 30% of Ontario's aggregate is supplied from quarries. Ideally, the site has a thin layer of overburden that is selectively stripped and initially stored in earth berms surrounding the property. Blast holes are drilled into the bedrock and fired to reduce the rock to pieces which can be removed by front-end loaders and taken to the crushing plant for further processing into various sizes of crushed stone. Because the bedrock is usually of consistent quality throughout the property, a quarry tends to have a regular, symmetrical shape with high, vertical faces.

Unlike other forms of mining, there is very little waste rock to dispose of. An extensive amount of fill is required to make an acceptable slope to the quarry floor. As the face moves through the property, the quarry operator can progressively use the overburden to backfill the worked out edges, which are then graded and seeded to form a continuous green strip surrounding the whole excavation.

Depending on the local drainage, a quarry may fill with water once the rock is removed in which case the after-use is primarily a recreational lake or wildlife habitat. However, a well-drained quarry can replace soil back onto the quarry floor and successfully return it to potential pasture land. Quarries may also provide a community with an excellent area for an industrial park, a storage area, or a sanitary landfill site because heavy truck traffic routes and screening from public view have already been established. In contrast, the Royal Botanical Gardens in Hamilton and the Butchart Gardens in Victoria, B.C., provide more exotic examples of quarry after-use.

The second type of aggregate extraction, pit mining, is the method used to remove unconsolidated material or glacial deposits of sand and gravel. This is the most common method of aggregate extraction in Southern Ontario. It is also the most prolific type of operation due to the large demand for sand and gravel in construction and due to the relatively small size of most deposits. A producer may extract from several locations on the property in order to mix or blend the material so it will meet the specifications required by road engineers. This sometimes makes progressive rehabilitation difficult because the operation is not consistently moving in a specific direction.

Shallower pit areas can be contoured and graded to a safe slope without requiring the large amounts of backfill which are needed in a quarry operation. By continuously removing small sections of overburden from the front working face and placing it on the mined-out pit floor, the producer can follow the sensible sequence of keeping the disturbed area on the property to a minimum. This will reduce the environmental impact and keep the rehabilitation deposit required by the Pits and Quarry Control Act as small as possible.

Since the aggregate industry produces a commodity that is very bulky and therefore, not easy to transport, the operations are most economically located close to large urban markets. In Canada, 68% of all aggregate producers are located within 8 kilometres of a populated centre. Trucking costs make up over half the delivered price. The importance of being close to the demand area is emphasized by the following fact. The Metro Toronto market consumes roughly 24 million tons of aggregate per year. If this sand, gravel or crushed stone was trucked an additional kilometre per metric ton, an extra 5.5 million litres of fuel would be consumed.

While the proximity of this resource to the market is a major economic factor, it also increases the producer's visibility to the public. Hence, the need to camouflage the site perimeter and the demand for improved rehabilitation practices are a constant challenge to members of the aggregate industry. This dilemma cannot be resolved by banning aggregate producers to Northern Ontario where they cannot be seen, but rather by increasing our knowledge of land rehabilitation so that aggregate producers will be welcomed as neighbours.

As city borders expand, exhausted pits have been surrounded and incorporated into the urban landscape. In Toronto, for instance, there are at least 80 sites which have been altered to become a productive part of the urban community. Some examples of this type of re-development include Christie Pits, a recreational park; a subdivision in Scarborough, once the location of a gravel operation; the subway service yards for the Toronto Transit Commission, situated in a depression caused by gravel extraction; and, Jane Street, just north of Alliance Avenue, passes through a now rehabilitated pit.

To promote rehabilitation projects and to commend companies and corporations for their exceptional efforts in turning old pits and quarries into productive after-uses, the Aggregate Producers' Association of Ontario periodically presents a Bronze Plaque Award. Our member companies annually participate in a property improvement award programme which over the past decade has yielded a variety of "before and after" examples of land management projects. The types of rehabilitation that have been accomplished range from housing development and sanitary landfill sites to agricultural land and golf courses.

As potential aggregate land becomes depleted or inaccessible because of incompatible land uses (such as housing over or adjacent to prime deposits), the producers will seek new reserves in more rural areas. Therefore, the emphasis on restoring agricultural land to a productive state is now in the spotlight.

The recent revisions to the Foodland Guidelines by the Ministry of Agriculture explains how new aggregate operations should consider certain specialty crop areas and basically rehabilitate them to the same level of production.

Because of economic reasons, legislation, and the public image of aggregate producers, the aggregate industry regards rehabilitation as extremely important. The argument that aggregate extraction is only a temporary land use has been strengthened by the success of current rehabilitation projects. It would be safe to say that sand, gravel and crushed stone will continue to be the main building blocks for urban growth and that a need for innovative methods of rehabilitation will be inevitable. In Canada alone, 420 million metric tons of mineral aggregate was produced in 1980, a figure representing 7,800 hectares of land being utilized and in need of rehabilitation. Although the present conditions in Ontario do not necessarily duplicate those in other provinces, they are indicative of situations which may develop in the more densely populated areas across Canada.

Thus, aggregate producers encourage representatives of the land reclamation profession to help their industry meet the creative challenge of improving techniques for pit and quarry rehabilitation in the future.

REHABILITATION OF AGGREGATE EXTRACTED LANDS FOR AGRICULTURAL PRODUCTION IN ONTARIO: PROBLEMS AND PROSPECTS

Wendy E.J. Worthy
24 Upton Crescent
Guelph, Ontario
N1E 6P3

ABSTRACT

During the original presentation, slides were used to illustrate: pre-legislation abandoned pits; pits occupying good general agricultural land with agriculture as the proposed after use; and, primarily, common problems associated with agricultural rehabilitation. Remedial measures were suggested for each problem.

The following paper has been summarized from one chapter of the author's M.Sc. thesis which was conducted at the University of Guelph. Included for each of the sequential phases of an extractive operation -- 1. site pre-planning; 2. stripping and stockpiling soil; 3. reapplication of soil; and 4. post-rehabilitation management -- are highlights of common problems associated with agricultural rehabilitation. General solutions are listed for each phase of the operation.

The paper is concluded with some prospects for the future.

INTRODUCTION

Industries which result in surface disturbance of land may have a genuine desire to carry out good rehabilitation. However, there are many problems that can be, and often are, encountered in any or all of the various sequential phases of operation: site pre-planning; stripping and stockpiling overburden, subsoil and topsoil; reapplication of overburden, subsoil and topsoil; post-rehabilitation management; and the costs of these operations.

According to existing legislation in Ontario, rehabilitation must accompany sand and gravel extraction. Although extraction and rehabilitation have to be planned to complement one another, this paper discusses problems and solutions in relation to agricultural rehabilitation only.

Terminology

Before moving on to the main body of text, it is first necessary to clarify terminology. The terms restoration, rehabilitation and reclamation are used interchangeably in the literature.

Yundt and Augaitis (1979) have stated that, with respect to disturbed land, rehabilitation generally refers to the returning of the land to some degree of productivity and to a use which is harmonious with the surrounding landscape. Therefore, at least within the confines here, the term rehabilitation carries the connotation of returning the land to a former capacity in terms of agricultural capability.

Reclamation is used in the context of simply reinstating the land to some use, not necessarily agriculture and not to its pre-mined productive capacity. Presently, depending only on the objectives of the sand and gravel producer, a pit may be rehabilitated (which includes returning to an equivalent or higher capability where agriculture is concerned) or reclaimed. Most examples in Southern Ontario to date have been reclamation (to recreation, for example), although this trend may be changing.

In terms of the Canada Land Inventory (C.L.I.) soil capability for agriculture, one can think of rehabilitation as having class 1 land returned to class 1 and class 2 land returned to class 1 or 2, and so on. Reclamation can be thought of as returning class 1 to a lower class, for example, or to some alternative use. Thus, rehabilitation can be thought of in terms of the soil capability class after disturbance being equivalent to or greater than before disturbance.

The term 'restoration' is used where no implications are being made as to the after-use; simply that the land is being or has been repaired.

Site pre-planning

This term implies that operation and rehabilitation of the site is comprehensively planned prior to initiation of extraction. Principal aspects of the planning sequence according to Coates (1980) are: comprehensive exploration and analysis of the deposit (to prove its worth); inventory of surface features (soil survey); determination of a long-term site use program (determine whether or not the end use can be agriculture); analysis of all major surface and subsurface characteristics; identification of constraints and opportunities; and synthesis of plans to meet any number of specific objectives (for example, agricultural after-use and a certain tonnage to be extracted per year). A very similar set of components to be included in preparation of a restoration plan has been presented as guidelines by the Land Conservation and Reclamation Council (1977) of Alberta.

The primary objective of site pre-planning in agricultural land rehabilitation is to determine if it is feasible to return the site to its former capability. Pre-planning for rehabilitation to agriculture will not only determine if the site can be returned to as high a capability as it was before disturbance but (if this is decided to be feasible) it will ensure that the final plan is in accordance with that goal. "Strict supervision of each phase is essential because a single ill-timed or inadvisable mechanical operation may undo many of the accrued benefits of an otherwise sound restoration programme" (Ministry of Agriculture, Fisheries and Food, 1971).

pre-planning - general problems:

-total absence of restoration planning prior to initiation of excavation

-pre-planning that is not operational; i.e. the plans are drawn only to satisfy government requirements for licensing and then are not or can not be implemented

-pertinent data (location of water table, depth of extraction, stratigraphy below pit floor) may be difficult if not impossible to collect

-fluctuating water table

-deciding on the most-suitable after-use and whether rehabilitation is possible or just reclamation when agriculture is chosen as the after-use

pre-planning - general solutions:

-enact laws which require progressive rehabilitation, a return to former capability and comprehensive pre-planning stating the planned after-use

-careful attention should be paid to the details of planning, making every effort to collect all pertinent data and to draw the plans so that they are practical and workable

-more emphasis should be placed on implementing and monitoring these detailed plans

-record soil resources (major soil types) and assess the inherent quality of the land prior to working include notes on the crops presently on the site and on similar adjacent land

-involve the public some time prior to completion of the plan

Stripping and stockpiling

The majority of literature and legislation is in agreement that topsoil (organic A horizons) should be stripped and stored separately from subsoil (B horizons) as should overburden when considering rehabilitation which includes maximizing vegetation yields (McRae, 1979; Power et al, 1979). For all analyses in this study, topsoil has been equated with the plow soil (Ap horizon) and the organic layer where the soil has never been plowed (Ah horizon). Any other A horizon (Ae, for example) has been treated as subsoil. Indications are that a total of between 70 cm and 1 metre of topsoil and subsoil are required to obtain optimum plant productivity (Power, 1978) which is in general agreement with the depth requirements for class 1 soil according to the C.L.I. capability system.

Experience shows that stripping operations should occur only when the soil is relatively dry during the warmer months to avoid breaking down structure and causing compaction. Thus, stripping should not be allowed after a heavy rain.

Little research has been conducted on the effect stockpiling has on the quality of topsoil. Consequently, much controversy has arrisen as to whether it deteriorates over time or not. If one can draw meaning from legislation stipulating the avoidance of stockpiling and strict controls regarding any stockpiling that is done, one might conclude that ill effects must occur. It is simplest to avoid the controversy whenever possible by progressively rehabilitating the mined area as is recommended by law in Ontario and many parts of the United States. Where stockpiling is unavoidable, quickly establish a vegetative cover to avoid erosion losses. Weighing positive benefits against negative effects is impossible, especially when the time dimension is included, without further research and experimentation. McRae (1979) hints that some deterioration is inevitable.

stripping and stockpiling - general problems:

-at what depth or depths and under what conditions should stripping occur?

-what machinery should be used; what is available is not always the best

-should soil be stockpiled?

-where should stockpiles be located?

-how long can topsoil be stockpiled without undergoing a change in composition?

-in some cases, too much overburden leads to a problem storing it; in other cases, too little overburden leads to trouble stripping and separating it

stripping and stockpiling - general solutions:

-strict supervision of all operations to ensure that specified depths are adhered to

-everyone involved (including machine operators) must be clear on the objectives and their role

-careful handling of subsoil and topsoil when it is moved; avoid moving it more than once (use progressive rehabilitation) or moving it under wet conditions

-preserve topsoil and subsoil separately and as much overburden as necessary to provide at least 20 cm of topsoil, 70 to 100 cm in total, providing these quantities were present prior to working

-vegetate stockpiles if to be stored longer than 30 days
-use of a motorized scraper is recommended to carefully control depth of topsoil removed (McRae, 1979)
-topsoil or subsoil should not be contaminated by gravel (stones) or overburden

Reapplication of soil

McRae (1979) emphasizes that the actual replacement of soil is the most critical step in restoration. Assuming that topsoil, subsoil and overburden were stripped (and stockpiled) separately, the problem then becomes one of reapplying the 'layers' in the proper order, without mixing, at an even depth and density.

A common occurrence has been the initial overgenerous spreading leading to a shortage of soil, particularly topsoil, in final areas to be restored (McRae, 1979). Bulk densities must be taken into consideration if the final thickness is to be correct. The total thickness of suitable material that should be placed on the spoil (pit floor) can be a matter of controversy and difference of opinion (Omodt et al, 1975). Most evidence indicates that 70 cm to 1 metre is adequate to attain pre-mined productivity, with more needed in coarse-textured and/or stony soils (Ministry of Agriculture, Fisheries and Food, 1971; McRae, 1979).

An increase in the density of a soil as a result of applied loads is termed soil compaction (Baver et al, 1972). Usually, the overall result is a decrease in crop production (Anonymous, 1979a). Compaction of the soil can be minimized or avoided by use of smaller machinery (Larson, pers. comm.) and by respreading soil under relatively dry conditions (Anonymous, 1979a; McRae, 1979). The more usual route is to attempt to eliminate compact layers, with the use of subsoilers or chisels, after thay have been formed (Anonymous, 1979a; McRae, 1979).

Another process which must be considered at this stage of operation is the final contour planned for the site. Slopes must be shaped and graded to allow surface drainage and to avoid steep, long slopes which are highly erodible (Stiller *et al*, 1980).

reapplication of soil - general problems:

- compaction of soil layers as they are reapplied
- replacing topsoil on the bottom and overburden on the top
- mixing topsoil and subsoil or overburden
- leaving the land too level or too steep
- initial overgenerous topsoil application resulting in future shortage
- what depths are required to meet the objectives (after-use)? when toxicity problems exist?
- problems primarily deal with application of technology; engineering and agronomic priniciples dealing with soil, fertility and structure have to be utilized

reapplication of soil - general solutions:

- avoid forming compact layers of soil by not moving it under wet conditions and by the use of tracked equipment
- level (contour) and rip the pit floor to break up compact layers thereby promoting natural drainage
- each layer -overburden, subsoil, topsoil - should be reapplied in its original order, breaking up compact material before putting back the next layer
- each layer should be contoured to promote natural drainage and avoid erosion
- keeping depths as near to original as possible may avoid controversy; follow existing legislation
- place toxic materials at depths where plants cannot reach them
- compaction may be prevented by performing wet reclamation: when soil contains less than 15% clay, a slurry can be produced (soil/water = 1/1.5) and piped into pens, allowed to settle and drain for 1 to 2 years. There is no compaction with the wet slurry method (Mackintosh, pers. comm.)

Post rehabilitation management

Much legislation now includes restoration to pre-mined conditions including contours, vegetation and productivity (capability). In order for this to be carried out satisfactorily, the final and often neglected step should be a period of cropping and management designed to build up soil structure and re-establish the network of pores and fissures, by which the soil drains, which is destroyed during soil movement (McRae, 1979).

For an agricultural after-use, treatment and cropping in this period should include a legume/grass mixture and manure. It must be emphasized that the primary objective is the restoration of soil structure, not agricultural production (M.A.F.F., 1971). With respect to reclaiming just to establish vegetation, species are chosen and soil amendments are made so that the area will be self-sustaining and need no further after-care. In contrast, for agricultural rehabilitation, post-rehabilitation management is vital for many years (Thirgood, 1978). Five years is the recommended minimum by agricultural experts (S.C.L.S.E.R.P., 1979) as is evidenced in the United States legislation.

post-rehabilitation management - general problems:

-total absence of management after the site is planted with its first vegetation

-attempt at management by non-expert leading to a lack of expertise in recognizing problem areas and knowing how to correct them

-monitor agricultural production rather than soil properties

-physical and chemical restrictions: compaction, sodium, low pH, alkalinity, salinity, mixture of topsoil and subsoil, no topsoil, dissolved heavy metals, sulfate ion, geography, altitude

-climate can be too severe: low precipitation, too much precipitation, cold, short photoperiod (growing season), permafrost in far North

post-rehabilitation management - general solutions:

-pre-plan to include a period of post-rehabilitation management by experts for a minimum of five years

-make primary objective the restoration of soil structure, agricultural production secondary

-test the soil to determine appropriate quantities of fertilizer; monitor this regularly

-examine soil yearly for localized problem areas (compacted, poorly drained patches); amelioration of these

-use only comparatively small machinery, when the soil is relatively dry, when preparing the seed bed

-select proper species: use a nurse crop (rye) or a well-established grass/legume mixture to improve structure, increase organic matter content for one or two seasons; use large quantities of manure (or sludge) to improve soil structure and increase nutrient levels

-cut grass before it matures as maturity reduces root vigour

-keep grazing animals off for at least the first year

-most physical restrictions can be overcome by proper use of present technology; including prevention, timing, equipment, soil amendments

-plan the whole operation with a sound knowledge of prevailing climate

-irrigation to increase value of crop grown or to permit vegetation in areas with little rainfall.

Costs of rehabilitation

Although not actually a phase of the rehabilitation operation, the restrictive or prohibitive nature of costs is a vital component in determining what work may actually be done. In the past, due to the profit motive, most extractive industries dismissed any major reclamation schemes as cost prohibitive (Oxenham, 1966). More recently, costs are seen as restrictive (rather than prohibitive) and perhaps, depending on the existing legislation controlling restoration, are simply passed on to the consumer as part of the costs of production (Schuman et al, 1976; Anonymous, 1979b). It is felt that, since most legislation includes bonds or security deposits for reclamation, it will increasingly become the practice to pass the cost on to the consumer.

Another aspect of cost is the actual cost of licensing an extractive operation (planning consultants, hearings). Presently in Ontario, this may be prohibitive for many small companies and restrictive for larger companies. An example has been set by TCG Materials Limited, Brantford, Ontario, that, through excellent pre-planning, the time and cost of gaining a licence can be cut considerably (Anonymous, 1980a). It has also been proven that costs of rehabilitation are minimized through use of a progressive rehabilitation scheme (Anonymous, 1980b).

CONCLUSIONS

Results of the University of Guelph study (Worthy, 1982) indicated that 60-70% of sites had been successfully rehabilitated to agriculture in the past. Obviously, with present technology, proper pre-planning, careful practice and good legislation, including enforcement of regulations, successful rehabilitation to agriculture is possible -- but to make it work someone has to really believe in and want to accomplish the rehabilitation. Regardless of whether that someone is the landowner and/or the contractor and/or an employee of the Ministry of Natural Resources, they can make the difference between successful and unsuccessful agricultural rehabilitation.

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FARMING AFTER GRAVEL EXTRACTION: TENDER FRUIT

Sarah B. Lowe
Supervisor, Rehabilitation and Property Improvement
TCG Materials Limited
P.O. Box 1390
Brantford, Ontario
N3T 5T6

ABSTRACT

Rehabilitation of sand and gravel pits into productive farmland has become an important issue in southern Ontario. One result is a recent revision of the Ontario Foodland Guidelines Policy concerning mineral aggregate extraction and prime agricultural land, which requires establishment of similar crop potential on restored lands.

One pilot project involves rehabilitation of two different sites within TCG's sand and gravel pit in a prime fruit growing area of the Niagara Region, in the Town of Pelham. Results show that orchards of tender fruit can be grown successfully, and future plans are for the progressive re-establishment of orchards across the property.

Key stages in the rehabilitation process are as follows: preplanning to prepare detail site plans; shaping extracted areas according to predetermined contours to provide good air drainage; careful stripping, storage and replacement of topsoil and subsoil; improvement of soil conditions by deep cultivation and stone picking; and use of alfalfa as a hay crop for several years before planting fruit trees. To rehabilitate silt ponds, additional treatment is needed to provide adequate drainage of water, on account of the underlying fine sand, silt and clay. This contrasts with rehabilitation of sandy pit floor areas, which have excellent drainage.

Costs of rehabilitation are similar to average land values for orchards in the area.

INTRODUCTION

TCG Materials' Fonthill Pit is a sand and gravel operation situated on the Fonthill Kame in the Town of Pelham, Region of Niagara. The Kame is a valuable deposit of sand and gravel, which is becoming scarce in the Region. It has excellent properties for concrete sand, brick sand and road gravel.

The Kame is also the basis of a valuable fruit industry. Orchards thrive on the well-drained, sandy soils and benefit from the mild climate due to the nearby Lakes Ontario and Erie. Much of the agricultural land produces tender fruit such as sweet and sour cherries, peaches and grapes, as well as the less demanding apples, plums and pears.

The Kame is, therefore, the site of a potential land-use conflict between the aggregate and agricultural industries, unless orchards removed for extraction purposes are later re-established.

Licensed reserves of sand and gravel on the Kame will be exhausted in a few years. New applications are currently being reviewed by local, regional and provincial levels of government, with substantial interest and involvement from public groups. The issue of tender fruit land and its reinstatement following extraction is a major consideration in the planning process.

The two main government bodies involved are the Ontario Ministry of Natural Resources (MNR) and the Ontario Ministry of Agriculture and Food (OMAF). MNR has a mandate for resource management and control, with a dual approach through Legislation[1] and Resource Planning Policy. The latter provides a framework to municipalities for mineral resource planning, including their responsibility to protect mineral resources within reason and to provide policies to permit the establishment of new pits and quarries.

Under the Ontario Ministry of Agriculture and Food, the Food Land Development Guidelines[2] concern the preservation of prime agricultural land and specialty crop areas. A recent Revision to Guidelines states: "Mineral aggregate extraction ..... shall not be permitted on specialty crop lands in the areas noted in Section 3.16.1 unless documentation is provided to reasonably show that: (a) the site can be rehabilitated for agriculture to allow production of the same acreage of the same specialty crops at the same level of productivity and (b) there will be no effect on climate or micro-climate on which the area may be dependant for specialty crop production" (Section 3.16.1 refers to the major fruit growing areas in southern Ontario and includes the Fonthill Kame).

It is clearly a good time to assess the "state of the art" with respect to rehabilitation for tender fruit. Agricultural rehabilitation involving a variety of crops has been occurring in southern Ontario for several years[3]. This paper concerns one site owned and operated by TCG Materials Limited, in a fruit-growing area of the Niagara Region.

RE-ESTABLISHMENT OF ORCHARDS ON EXTRACTED LAND

As part of its aggregate operations in a 163 acre (66 ha) property near Fonthill, Ontario, TCG Materials has established two orchards on land previously extracted for sand and gravel: Montmorency sour cherries on a former silt pond, and apples on the pit floor. Current rehabilitation plans allow for continuous development of the entire property for orchard production, including a proposed extension of the present operation into an adjacent 60 acre (24 ha) parcel owned by the company but not yet licensed. The final area in orchards will be approximately 150 acres (61 ha).

Development of Orchards

Both orchards were established and maintained by company employees, with direction and assistance from Ecological Services for Planning Limited in Guelph, the Horticultural Research Institute of Ontario at Vineland and neighbouring fruit growers.

Two different areas of the property were planted representing different situations in the final rehabilitation plan. Pit floor areas where the apple orchard is located are more typical, while the silt ponds where the cherry orchard is planted, represent less than 15% of the final area to be rehabilitated. The ponds are extracted areas filled with fine sand and silt from the washing operation and are the only part of the property where any filling will occur.

Steps followed in developing the orchards are summarized on the following page.

Soil Conditions

The most important consideration here is drainage, which is excellent on the floor of the pit due to the well drained sand that is left, even after removal of the marketable sand and gravel in the deposit. The pit floor, without filling, is an ideal base for replacement of soil and establishment of orchards.

DEVELOPMENT OF ORCHARDS: FONTHILL PIT

	CHERRY ORCHARDS: SILT PONDS	APPLE ORCHARD: PIT FLOOR
1976/ 1977	First silt pond covered with 90 cm subsoil/topsoil. 100 Montmorency sour cherry trees planted (0.5 ha)	
1978/ 1979	Additional areas covered with subsoil/topsoil.	Subsoil/topsoil replaced on pit floor; planted with grass or birdsfoot trefoil (3 ha).
1980	Area expanded to 1.5 ha.	125 apple trees planted in sod: Delicious, Spy and Early Macs, on M7 root stocks (0.5 ha).
1981	200 more sour cherry trees planted. Orchards maintained with cultivation (1.5 ha).	Orchard maintained in grass sod.
1982	Drainage tile installed; stones picked. Additional areas covered with 1m sand fill, then either topsoil or topsoil/subsoil mixture.	Orchard maintained in grass sod.
1983	Orchard ripped with agricultural subsoiler across line of tile; stones picked. Alfalfa/timothy planted on areas (2 ha). Total area rehabilitated ponds 3.5 ha.	Orchard ripped with agricultural subsoiler; stones picked. Orchard worked and reseeded.

An initial limitation in parts of the silt pond was identified as poor drainage, resulting from the nature of the pond itself which contains fine sands, silt and some clay. In the area already planted with cherries, drainage has been greatly improved by installing drainage tile between each row of trees. In the remainder of the ponds rehabilitated more recently, good drainage was first established by placing a layer of sand fill at least one metre deep over the surface of the pond before replacing the subsoil and topsoil.

Fertility levels in the orchards vary to some extent with the nature of the replaced soil. Under our current practice of keeping the topsoil or A horizon separate from the underlying subsoil or B horizon while stripping, the nutrients and organic matter levels in rehabilitated areas are not substantially different from those found in undisturbed orchards. Where previous practices mixed the topsoil and subsoil, and where they had been stored for some time, the soil needs greater inputs of fertilizer and organic matter. It also has a higher pH value. To ensure improved levels of soil fertility and structure, an initial crop of alfalfa is now being grown for two or three years before planting fruit trees.

Growth and Production

With the exception of some cherry trees which were lost in the early stage of the program through poor drainage in specific areas (of the silt pond), plant survival has been excellent and growth of both orchards satisfactory. Trees are growing vigorously and have healthy foliage, as reflected in analysis of leaves taken annually by the Horticultural Research Institute of Ontario (see table below).

TABLE - leaf tissue analysis of sour cherries and apples (1982)

		CHERRIES		APPLES
		OLDER TREES	YOUNGER TREES	
Nitrogen	Percent	2.18	2.64	2.58
	Rating	D+	A-	A
Potash	Percent	1.84	2.31	1.93
	Rating	A	A+	A+

Ratings: D+ = Mildly Deficient
A = Adequate
A- = Low Adequate
A+ = High Adequate

Both apple and cherry orchards are now beginning to bear fruit. Cherry yields in 1983 were encouraging: trees in well drained locations produced approximately 18 quarts (25 lbs) each, which is a normal yield for young trees beginning to bear. The crop was picked by an Ontario Ministry of Agriculture and Food Agricrew (see photograph) and was sold to the local Vineland Growers Cooperative. Under our improved soil conditions, we expect that the orchard will produce at satisfactory levels.

Future plantings will continue to extend the cherry orchards on the silt pond and also on more recently rehabilitated areas of the pit floor.

Land Shaping

The original site plans for the operation (which showed estate lots as an after-use) are presently being revised to accommodate tender orchards as the final after-use, including the proposed extension of the operation into the 60 acre parcel not yet licensed[4]. By considering the total property as a whole, a carefully designed contour plan has been devised to ensure continuous flow of air across the property. This is essential to avoid the development of frost pockets in the spring, which would seriously limit the production of tender fruit.

Since 1982, rehabilitation practice includes careful land shaping according to the plan before replacement of subsoil and topsoil.

CONCLUSIONS

1. Existing orchards of sour cherries and apples planted from 1977 to 1981 show that fruit trees can be established successfully on extracted land. We feel there is no reason, therefore, why this Fonthill Pit cannot be returned to viable commercial production of tender fruit.

2. Initial limitations resulting from poor drainage on the silt pond have been corrected, and drainage is excellent on the pit floor where the majority of progressive rehabilitation is now taking place.

3. Soil properties can be preserved if topsoil is stripped and replaced separately from the underlying subsoil, as is our present practice. Establishing a crop of hay for two to three years before planting fruit trees will further ensure a quick return to normal soil conditions.

4. Costs of rehabilitation are approximately $5,000. per acre ($12,500. per ha) plus establishment of hay crops and orchards.

Picking tart cherries on rehabilitated land: 6 year old orchard planted on a former silt pond (TCG Materials Limited: Fonthill Pit, Town of Pelham, Region of Niagara).

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LIST OF CONFERENCE DELEGATES

J.J. Armstrong	Ontario Ministry of Transportation & Communication Brantford, Ontario
B. Angster-Beckett	Laurentian University Sudbury, Ontario
Alex S. Ansell	Ontario Hydro Aurora, Ontario
Brian D. Bailey	Manitoba Dept. of Energy & Mines Winnipeg, Manitoba
Peter J. Beckett	Laurentian University Sudbury, Ontario
David Blunden	Laurentian University Sudbury, Ontario
Peter Bojtas	Keir Addison Mines Ltd. Toronto, Ontario
Daniel J. Boivin	Universite de Laval Quebec, Quebec
Marie Boehm	Monenco Consultants Calgary, Alberta
Gordon Boutilier	Cape Breton Development Corporation Sydney, N.S.
George D. Booth	Ministry of Natural Resources Wingham, Ontario
Bernard W. Brooks	Noranda Mines Ltd. Noranda, Quebec
Walter F. Brown	Walter Brown Consultants Mississauga, Ontario
Mary Beth Cassidy	TransCanada Pipelines Toronto, Ontario
Paul Cosburn	MacLaren Plansearch Toronto, Ontario
Charles DeAngelis	Grass Growers Inc. Plainfield, New Jersey

Ralph M. Dell	Ministry of Transportation & Communications Downsview, Ontario
Joe Dol	Verdyol Mulch of Canada Cookstown, Ontario
David Downing	Sunburst Resources Ltd. Calgary, Alberta
Tony S. Dai	Syncrude Canada Ltd. Edmonton, Alberta
Virgil M. Edlin	Eldor Mines Saskatoon, Sask.
Michael D. Evans	Earthscape Consultants Edmonton, Alberta
Brent W. Evered	Department of Natural Resources Fredericton, N.B.
Karl Fiander	Otto Pick & Sons Seeds Ltd. Richmond Hill, Ontario
Jean Gagnon	Queens University Kingston, Ontario
Monica Gewurz	Landscape Architect Guelph, Ontario
Doug Harvey-Smith	National Energy Board Ottawa, Ontario
Marika Hare	TransCanada Pipelines Toronto, Ontario
Jennifer A. Hansen	Reid, Crowther & Partners Ltd. Calgary, Alberta
Sharon A. Haxton	Ontario Hydro Toronto, Ontario
R. Paul Johnson	Oseco Inc. Brampton, Ontario
Paul King	Alberta Forest Service Edmonton, Alberta
Margarete Kalin	Institute for Environmental Studies Toronto, Ontario

Brett Lucyk	Ecoplans Ltd. Guelph, Ontario
David A. Lloyd	Alberta Energy & Natural Resources Edmonton, Alberta
Sarah B. Lowe	T C G Materials Ltd. Brantford, Ontario
Doug MacMillan	Otto Pick & Sons Seeds Ltd. Richmond Hill, Ontario
Wayne Marshall	TransCanada Pipelines Ltd. Toronto, Ontario
John S. Masham	Ministry of Natural Resources Toronto, Ontario
C. Philip Mason	Nova Corporation Calgary, Alberta
Nancy McInnis-Leek	Washburn & Gillis Associates Dartmouth, N.S.
Ross Milne	TransCanada Pipelines Toronto, Ontario
Ian Moncrieff	Union Gas Ltd. Chatham, Ontario
Victor Morton	Mine Waste Reclamation Ltd. Kitchener, Ontario
Sandra D. Margison	National Energy Board Ottawa, Ontario
E. Mackintosh	E S P Ltd. Guelph, Ontario
Garry J. Mann	Esso Minerals Canada Calgary, Alberta
Ian Marshall	Environment Canada Hull, Quebec
James D. Parkin	Ministry of Natural Resources Owen Sound, Ontario

Peter G. Prier	Ontario Energy Board Toronto, Ontario
Margaret Pigot	McGill University Montreal, Quebec
T.H. Peters	Inco Ltd. Copper Cliff, Ontario
Janice A. Pelton	Ministry of Natural Resources Toronto, Ontario
Holly Quan	Trans Alta Utilities Corp. Calgary, Alberta
A. Reynolds	Walker Industries Thorold, Ontario
Prof. K. Rutherford	Queens University Kingston, Ontario
J. Kent Stewart	Hickling-Johnston Ltd. Edmonton, Alberta
H.P. Sims	Alberta Research Secretariat Edmonton, Alberta
V. Singhroy	Ontario Centre for Remote Sensing Toronto, Ontario
Dawn Spires	Northern Terrestrial Consultants Sudbury, Ontario
Stewart Sampson	Brunswick Mining Bathurst, N.B.
Susan Singh	Ontario Ministry of Agriculture & Food Toronto, Ontario
Harold Spence	Verdoyl Mulch of Canada Cookstown, Ontario
Jack Thirgood	University of British Columbia Vancouver, B.C.
Walter Watt	TransCanada Pipelines Ltd. Toronto, Ontario
David Walker	Walker & Associates Ltd. Edmonton, Alberta

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